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THE CLYDE SERIES OF SOILS.

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INTRODUCTION.

The surface soils of the Clyde series are dark gray, dark brown, or black in color. The subsoils are gray or sometimes yellowish in color and mottled with yellow and gray, but not with red, in practically all cases. The surface of nearly all members of the series is level, with only slightly rolling or ridged areas where some of the types rise above the general level of the surrounding country. In nearly all of the more extensive areas of their occurrence, and in all of the smaller tracts, the surface of the different soils of the Clyde series is depressed below that of surrounding soils of other series. The soils of the Clyde series have been formed either by direct deposition as sediments in old glacial lakes, which have since been drained by natural processes, or they have resulted from the accumulation of more or less mineral matter and a large amount of partially decayed organic matter in small lakes, ponds, and swampy depressions occurring within the glaciated region of the northeastern and north-central States. In the majority of instances the larger areas of the soils of the Clyde series occur within more or less well-drained basins of old glacial lakes.

The soils of the Clyde series grade into deposits of muck and peat on the one hand and into the more completely drained soils of other series of the glacial lake and river terrace province, or of the glacial and loessial province, on the other.

Note.—This bulletin discusses the origin, characteristics, and uses of the Clyde series of soils; it is suitable for distribution in New York, Ohio, Indiana, Michigan, and Wisconsin.

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Another distinction which is of general but not quite universal application, is that the subsoils of the different types of the Clyde series, particularly the subsoils of the more extensive and heavier loam and clay soils, have been found to be calcareous. Many analyses of these subsoils have been made, which disclose from approximately 1 per cent of lime carbonate to as much as 25 per cent of that material. Usually the more sandy members of the series are not so well supplied with lime carbonate as the heavier textured types.

In their natural condition practically all the different soils of the Clyde series in all occurrences which have been encountered are rather poorly drained. They require artificial drainage to become of agricultural use but are then very productive soils for the growing of the staple farm crops of the region in which they occur and for the production of special crops where market facilities are favorable.

GEOGRAPHICAL DISTRIBUTION.

All of the known occurrences of the soils of the Clyde series are localized within the territory immediately to the south of the Great Lakes. The largest areas are to be found in the Maumee Valley in Ohio and Indiana; in the valley which stretches to the southwest from the shores of Saginaw Bay, in Michigan; and along the shores of the St. Clair River, Lake St. Clair, and the Detroit River in southern Michigan. The latter region is a connecting strip between the two larger areas. In addition there are considerable areas of soils of the Clyde series in northern and western New York, associated with the glacial lake deposits of the St. Lawrence River Valley and the Lake Ontario Plain; in northern and central Indiana, associated with the great glacial river terraces of the Kankakee and other rivers; and in southeastern Wisconsin, in a glacial lake area which extends from the southern end of Green Bay to the vicinity of Fond du Lac. (See fig. 1.) These areas include all of the most extensive localities within which soils of this series have been encountered, and within which additional large areas may be expected to be mapped as the work of the Soil Survey progresses.

There are, however, many smaller isolated areas of the soils of the Clyde series which are found in the smaller basins, drained lake areas, and swampy terraces of glacial outwash material which occur throughout the upland portions of the States bordering the Great Lakes. Although such areas may be individually of limited extent, their aggregate area will ultimately be found to be very large.

In addition many small disconnected areas of the soils of the Clyde series are found in low hollows and depressed level areas within the glaciated upland of the region immediately south of the Great Lakes, particularly in western Ohio and eastern and central Indiana. These areas represent tracts where the local drainage was

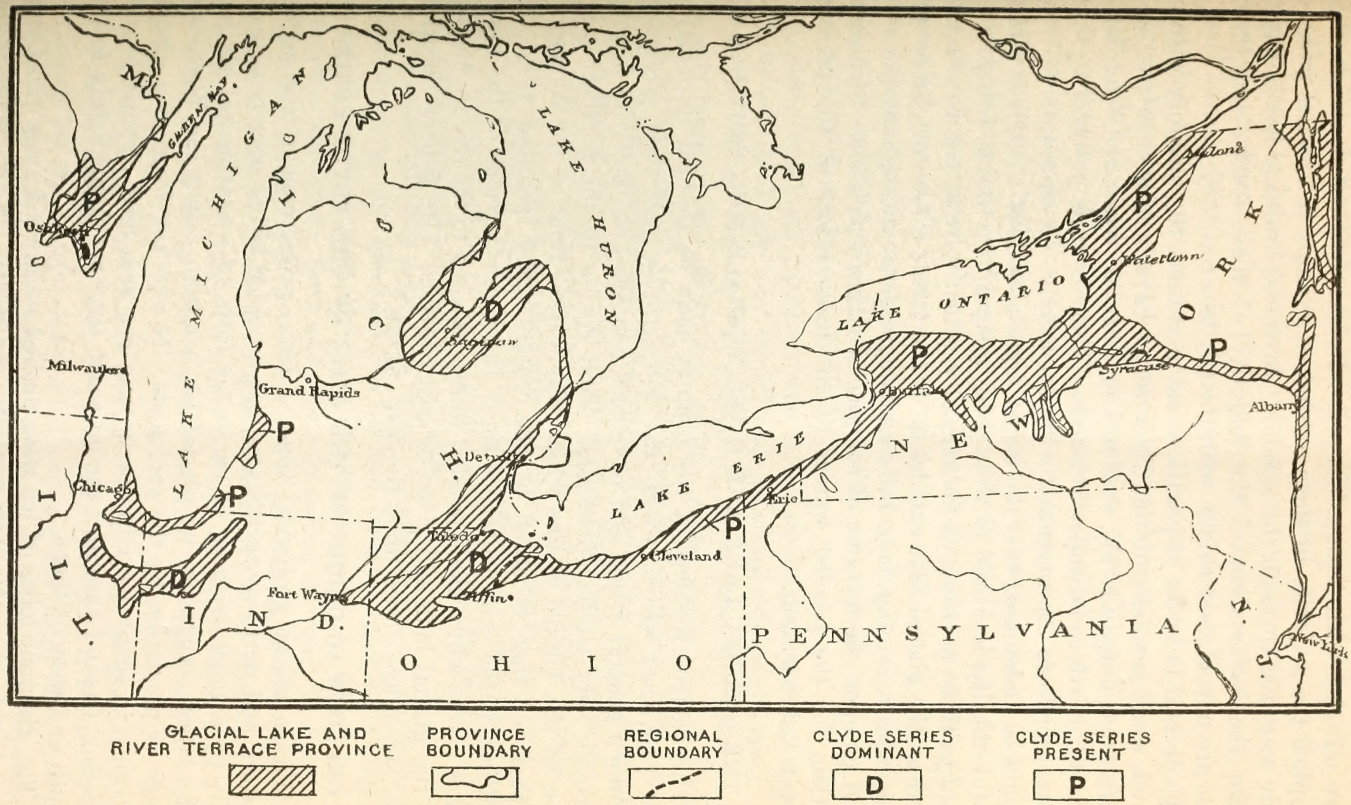

FIG. 1.—Sketch map showing regions in which the Clyde soils are found.

obstructed and where considerable accumulations of organic matter were mingled with the surface soil. Before artificial drainage was supplied the majority of them existed as swamps and swales irregularly scattered through the upland. Artificial drainage has brought about the reclamation of the majority of these tracts, and their soils are now classed chiefly with the Clyde series.

Expressed in terms of parallels and meridians, the territory within which some members of the Clyde series have been encountered extends from longitude 75° west to longitude 90° west; and from latitude 40° north to latitude 45° north. There is some probability that more northern occurrences will eventually be encountered. It should be understood that the larger areas of soils of the Clyde series are decidedly localized within these geographic limits, being confined to those portions of the territory which were at one time occupied by the glacial lake extensions of the Great Lakes, or else occurring within smaller lake beds and depressions throughout the upland or upon the terraces of the glacial rivers which once furnished outlets for the ponded waters of the predecessors of the present Great Lakes system.

THE GLACIAL LAKE AND RIVER TERRACE SOIL PROVINCE.

The various sections of the country may be divided into major soil provinces within which the soil-forming materials possess a common general origin and have been deposited or otherwise formed through very similar processes. That region in the northern portion of the United States which was at one time or for successive periods of time occupied by the waters which resulted from the melting of the continental ice sheet and those portions of the lower lands across which these ponded waters escaped to the sea are classed as the glacial lake and river terrace province. Its general location and extent are shown upon the map, figure 1.

GEOLOGICAL ORIGIN OF THE SOILS OF THE CLYDE SERIES.

Within recent geological times a large proportion of the northeastern and north-central States was occupied either once or repeatedly by a thick covering of ice in the form of a continental glacier. The latest occupation by glacial ice has been called the Wisconsin stage of glaciation by the geologists. It took the form of a glacial advance in many ice lobes occupying the area now covered by the existing Great Lakes and the adjacent territory immediately to the south and west of them.

The different lobes of ice were pushed southward from the Canadian highlands until they occupied practically all of northern and western New York, northwestern Pennsylvania, northern Ohio, and

Indiana, all of Michigan, northern and northeastern Illinois, nearly all of Wisconsin, and large areas in Minnesota and Iowa.

The form of the ice lobes and the general direction of their advance seem to have been greatly influenced by the basins now occupied by the Great Lakes. Thus, in the St. Lawrence Basin one of the more eastern lobes was deflected by the Adirondack Mountain mass, reaching its most southern limit at altitudes of 1,500 to 2,000 feet above the present sea level where its southward spread was terminated against the highlands of southern New York and northern Pennsylvania. The extreme southwestern portion of this lobe extended to northeastern Ohio, where it terminated at elevations of approximately 1,000 feet above sea level, occupying the rolling plain which forms the northeastern extension of the Mississippi Valley. Other lobes covered all of the southern peninsula of Michigan and extended across the low plateau of northern Ohio and Indiana, of northeastern Illinois and southeastern Wisconsin, terminating on the low plain of the upper Mississippi Valley at altitudes varying from 700 to 1,200 feet above sea level.

In practically all instances this latest advance of the continental glacier occupied territory which had previously been glaciated one or more times. During the period of its advance and occupation of this territory the Wisconsin glacier redistributed the unconsolidated material which already existed within the region, filling many of the deeper valleys which had been cut into the underlying rock. It also brought fresh material from the Canadian Highlands and from the more northern portions of the north-central States. In addition it derived a considerable amount of material from the local rock over which it passed. All of this material was deposited either during the occupation of the region by the glacial ice or during the slow northward recession of the ice sheet.

The material thus deposited usually consisted of a heterogeneous mass of coarse and fine particles derived from many diverse sources and laid down either in the form of ridged moraines, where the ice front was stationary for a considerable period of time; in the form of gently rolling till plains, where the glacial material was deposited beneath the ice in the form of ground moraine, or as stratified sand, gravel, and bowlder deposits where streams of water flowed from the ice front, or from caverns formed between the land surface and the ice.

As a result of these differences in the character of glacial action the general land surface of the area occupied by the ice was first smoothed by the glacial erosion of exposed surfaces, then further leveled by the filling of protected depressions through the deposition of glacial materials. Yet the final land surface maintained a considerable degree of irregularity in surface elevation through a failure

to obliterate the previous relief of the country and through the deposition to unequal thickness of the different classes of glacial materials.

The recession of the glacial ice during this latest state of glaciation undoubtedly occupied a long period of time as measured in years. It was accompanied by the formation of large volumes of water derived both from the melting of the ice and from the normal annual precipitation over the region. This water was forced to seek outlets to the sea through new channels cut across the moraines and till plains of the north-central States and through channels formed along the border between the ice and a higher lying upland which had been freed from its ice covering in the northeastern States. During the progress of the establishment of these new drainage ways there was an extensive ponding of the glacial waters within the lower lying areas included between the ice front and the elevated land areas of different characteristics which lay to the southward. This stage of deglaciation resulted in the formation of several large bodies of glacial lake waters along the southern limits of the present Great Lake system and of innumerable small glacial lakes held between the more elevated moraines and in depressions in the till planes of the glaciated upland.

The larger glacial lakes occupied successively lower levels along the ice front as the ice retreated, since successive channels opening to the sea were uncovered during the long period of glacial recession. Owing to this frequent change in level the students of glacial geology have been able to identify a large number of different glacial lakes which have been given different names. In some instances as many as 10 or 12 different stages of glacial lake occupation, possessing different outlets and giving rise to characteristic glacial lake sediments at many levels, have been identified.

For the purposes of the discussion of the glacial lake deposits which ultimately gave rise to the soils of the Clyde series it will hardly be necessary to outline the different areas occupied by even the larger successive glacial lakes. It will be sufficient instead to outline in a general way the largest areas within which these deposits were formed, to indicate the sources of the material which gave rise to this particular group of soils as distinct from other soils of somewhat similar mode of formation, and to show the processes through which the different soils of the Clyde series have been created.

It is probable that the first glacial lakes formed along the border of the receding ice occupied small areas around the southern extremity of Lake Michigan, where glacial Lake Chicago was formed, and a small area extending from the vicinity of Fort Wayne, Ind., eastward across the State line into Defiance, Paulding, and Van Wert Counties, Ohio, where the first stage of Lake Maumee existed. With a slow recession of the ice sheet the area of glacial Lake Chicago

was increased, covering what is now the southern end of Lake Michigan. In consequence, only small areas of glacial lake material now form the land surface around the southern extremity of that lake. In the case of Lake Maumee the gradual recession of the ice gave rise to the formation of glacial lake materials covering an area of more than 4,000 square miles in northwestern Ohio, northeastern Indiana, and southeastern Michigan. In fact, the entire Maumee Basin and the adjacent territory, extending from the vicinity of Fort Wayne, Ind., past Sandusky, Ohio, on the south and to the vicinity of Port Huron, Mich., on the north, was occupied by a succession of glacial lakes whose characteristic topography and distinctive soils now constitute the principal surface features of that region.

At the same time a considerable area of low-lying land to the south and west of Saginaw Bay, in Michigan, was occupied by glacial lake waters at several successive periods. It is probable that the total area formerly occupied by glacial lake waters around Saginaw Bay amounts to approximately 2,500 square miles.

A similar area was occupied by glacial lake waters standing at the lower levels around the head of Green Bay, in Wisconsin, and southwest past Fond du Lac. The total area of glacial lake sediments in the latter region is possibly as great as 1,000 square miles.

During these earlier stages of ice recession and glacial lake occupation the outlets for the ponded waters were through the Des Plaines River into the Illinois River, for Lake Chicago; past Fort Wayne into the Wabash River, for the first Lake Maumee; and around the "thumb" of Michigan through Lake Saginaw and thence down the Grand River to Lake Chicago for the more northern waters. As the ice still farther receded, a passage for the impounded water was uncovered to the eastward between the ice front and the higher lying plateau country of northwestern Pennsylvania and western New York. For a time, at least, an outlet was established through the Mohawk Valley, while at a later stage the drainage way through the St. Lawrence River was uncovered. Still later, marine waters occupied the St. Lawrence Valley and a small area around the outlet of Lake Ontario. Thus a series of glacial lakes was formed along the southern shores of Lakes Erie and Ontario and within the St. Lawrence Valley.

FORMATION OF GLACIAL LAKE DEPOSITS.

During all of these successive stages of glacial lake occupation, distinctive lake sediments were deposited at the different levels, descending from an altitude of about 800 feet for the higher stages of the more western lakes to the present level of the upper Great Lakes. In the more eastern areas south of Lake Ontario the elevated plateau

at the south maintained the first glacial-lake stages at altitudes as high as 1,100 feet in the Finger Lake region of central New York, while the later more extended glacial lakes in western New York occupied areas lying below 800 feet in elevation and thence declining to an altitude of 246 feet, the present elevation of the surface of Lake Ontario. At all of these elevations continuous or interrupted areas of lake sediments were deposited.

The materials which were reworked and redeposited as glacial-lake sediments were everywhere of diverse origin. They were derived immediately from the heterogeneous mass of stone, gravel, sand, silt, and clay which formed the glacial till. This mass of earthy matter existed either upon or in the ice mass and was set free by melting or it had previously been laid down by the ice in the form of moraines and other deposits. In some localities it is possible that the glacial lake waters also derived some material from underlying consolidated rocks where these were not covered by glacial deposits. Such occurrences were of very small extent.

In general, the largest amounts of material were contributed either by the glacial streams which flowed directly from the ice, by streams which flowed into the glacial lake basins from the uncovered but previously glaciated uplands, or through the direct action of waves and currents of the glacial lakes upon the till which formed the boundaries or the floor of the glacial lake basins.

The streams which were formed directly from the melting of the ice carried glacial materials of all sizes, which were sorted and deposited either in the form of long, low ridges chiefly consisting of gravel and sand, which are known as eskers, or as broad, low outwash plains usually sandy in their general character. In both cases the finer sediments were carried to positions more remote from the ice front and were deposited in the deeper and quieter waters of the glacial lakes.

Similarly the streams which flowed into the glacial-lake basins from the deglaciated uplands brought large amounts of material and this was partially or completely assorted to be deposited in the form of stream deltas near the outer margin of the lake areas. Frequently the coarser material was dropped in the form of low alluvial fans where the stream waters entered the lake. The finer materials from these sources were also carried to greater distances and deposited with the finer sediments derived directly from the glacier. There was thus a mingling, in the majority of instances, of upland glacial till, of local country rock material, and of materials contributed directly through the melting of the glacial ice, all deposited to form the different grades of glacial lake sediments.

Along the landward border of each of the larger lakes wave action played a considerable part in eroding both the glacial till and in some

cases the local country rock. This resulted in the formation of wave-cut terraces at the higher levels and in the deposition of sandy and gravelly beaches and bars concentrically around the margins of the lakes at different elevations corresponding to the different levels of the receding glacial lake waters.

The materials formed in the deltas of both glacial and upland streams and the material deposited along the shore lines usually constitute the coarser grained sediments of glacial lake deposition. It is in such areas that large stone and coarse gravel are most frequently encountered, while only smaller gravel and the different grades of sand are found in the outwash plains and in those portions of the stream deltas which were carried farthest into the lake areas. Elsewhere the finer grained sediments, such as sandy loams, loams, and clays, prevail.

In the smaller glacial lake areas, particularly where lake occupation existed only for a brief period, the finer sediments dominate.

In the case of all of the larger glacial lakes irregularities in the surface of the glacial till, accentuated in some instances by the existence of local belts of moraine, gave rise to very unequal depth of water within the lake area. In the case of the glacial Lakes Saginaw and Maumee, curved moraines, concentric with the lake-shore line, rose above the lake level at some period of the lake stage. The waters of the lake acted against these moraines in the same manner as against the upland till, forming beaches and distributing the coarser and finer sediments along these shore lines and through the deeper lake waters. Other portions of the till and of water-laid moraines rose nearly to the surface of the lake and the crests of these submerged ridges were subjected to a degree of wave action only less than that along the shore lines. In certain areas the force of the water was only sufficient to move and redistribute the finer grained particles, while the larger gravel and the bowlders remained practically in their former position, being somewhat accumulated at the surface through the removal of the finer earthy material. Where such action has taken place unquestioned glacial lake deposits sometimes present the anomaly of abundant glacial bowlders and of large cobblestones. In some instances it is even difficult to distinguish between glacial moraine or till and the feebly reworked glacial sediments derived through the action of shallow lake waters across ridges which rose nearly to the surface of the lake.

In other instances the drumlins and other glacial till ridges extended above the surface of the lake waters and only their sloping flanks and the lower lands between them were covered by glacial lake sediments.

In every instance in the larger glacial lake basins the silt and clay derived from the different sources outlined were deposited in

the deeper and quieter lake waters in positions more remote from the deltas of tributary streams and at some distance from shore-line borders. They usually rest either upon consolidated rock, upon glacial till, or upon the more sandy or gravelly materials which were sometimes deposited first as the ice retreated.

Thus the greater part of all of the glacial lake basins consists of marginal gravelly and sandy zones, of local sand plains and stream deltas, and of the heavier loam and clay deposits more remote from the sources of sedimentary supply.

When the waters of the different glacial lakes were gradually withdrawn and the bottoms of these lakes exposed to form a land surface there were many minor inequalities of elevation which gave rise to wide differences in the drainage features of the lake basins.

Areas lying between successive beaches frequently remained swampy. Shallow depressions in the broader lake plains still contained minor ponds and swamps. Only the higher lying areas and the more sloping surfaces became well drained immediately after the recession of the glacial lake. The broad level areas, occupied by the heavier clays and loams, together with all depressed areas within the glacial lake plains, remained swampy for a considerable period of time. In consequence large areas included within the glacial lake basins passed through a swampy stage which persisted in many instances until the occupation of the land by white settlers, and which has only been relieved to a partial extent through the installation of artificial drainage.

It is probable that water-loving grasses and the smaller forms of vegetation first occupied these swampy areas. It is certain that considerable areas of the swamp included within the glacial lake basins remained so poorly drained until within historic times that only a few species of trees found foothold within their limits, while in many instances considerable areas remained in the condition of treeless marshes or grass-grown swales.

In other instances areas somewhat better drained eventually became covered with a heavy stand of ash, elm, soft maple, tamarack, and other water-loving trees. In all cases the swampy conditions gave rise to the formation of large amounts of humus in the surface soil and this has given a characteristic dark gray, brown, or black color to the surface layer of extensive areas of the glacial lake deposits in the north-central and northeastern States. These give rise to the soils of the Clyde series. Conditions of more perfect drainage gave rise to light-gray or yellow surface soils which are classed in other soil series than the Clyde.

The different soils of the Clyde series, therefore, owe their origin to a complex series of events beginning with the glaciation of the northeastern and north-central States, followed by the retreat of the

continental glacier and the formation of large or small glacial lake and glacial stream terrace areas, which in turn was succeeded by the withdrawal of the lake waters and the formation of extensive swampy, or at best poorly drained areas within the lake basins, and ended by the accumulation of considerable amounts of partially decayed organic matter in the surface soils.

The soils thus formed have been rendered capable of agricultural occupation only through the installation of artificial drainage in the majority of cases. Many thousands of acres of these soil materials still remain poorly drained.

TOPOGRAPHIC RELATIONSHIPS OF THE SOILS OF THE CLYDE SERIES.

The greatest development of the glacial lake province in New York State occurs from the vicinity of the St. Lawrence Valley westward along the shore of Lake Ontario to the Niagara River.[1] In the St. Lawrence River counties the area within which the glacial lake sediments are developed is narrow, forming a belt varying from 5 to 15 miles in breadth along the shore of the river. Its surface is anything but smooth and the irregularities are due to the different elevations of the consolidated underlying rocks, which present an uneven and sloping surface, as well as to unequal deposition of the glacial till. Over materials of diverse origin and of uneven altitude the sediments of the glacial waters were deposited to greatly varying depths.

In general, the lowest elevations occur along the shore of the St. Lawrence River and around the eastern end of Lake Ontario. The surface of the sedimentary lake deposits consists of large and small level tracts which are interrupted by ridges of rock, by swells of moraine, and by hollows within which swamps still exist. Gradually this uneven surface rises toward the Adirondack border until the highest distinctly glacial lake deposits are found about 750 feet above sea level or about 500 feet above the waters of Lake Ontario and the St. Lawrence River.

Throughout this section of the glacial lake region there has been a sufficient degree of obstruction to surface drainage to give rise to the formation of swamps of large and small size, resulting in the formation of soils of the Clyde series. They are always to be found in locally depressed positions, which are not so poorly drained as the associated swamps but which are less well provided with natural drainage facilities than the surrounding upland soils. Many of the areas also accumulate local seepage waters from soils or rock areas lying at higher elevations.

[1] Bulletins Nos. 106, 127, and 145 of the New York State Museum. Glacial Waters in the Lake Erie Basin. Glacial Waters in Central New York. Geology of the Thousand Islands Region. By H. L. Fairchild and others.

A considerable part of the soils of the Clyde series in this section consists of the heavier clays, while smaller areas contain enough coarser material to constitute the Clyde fine sandy loam and fine sand.

The largest area of the glacial lake deposits of New York State extends from the vicinity of Syracuse to the Niagara River and from the southern shore of Lake Ontario to the bordering highlands which pass through the western portion of the State at a distance, roughly, half way between the Lake Ontario shore and the southern boundary of the State. From Syracuse to Buffalo, N. Y., the upper limit of the lake sediments lies approximately along the line which marks an elevation of 1,000 feet above sea level. At higher altitudes there were only local lake deposits, while even below the 1,000-foot contour line there are many higher lying ridges and hills which were probably not covered by lake waters for a sufficient period of time to give rise to distinctively glacial lake deposits.

This portion of the glacial lake province is also marked by great differences in altitude and surface configuration. Along the shore of Lake Ontario the surface of the land lies at 250 to 300 feet above tide level or approximately from the level of the lake to elevations of 50 feet above its waters. Thence a narrow belt, ranging from 10 to 15 miles in width from north to south, lies in the Lake Iroquois plain, formed at the latest stages of glacial lake occupation. This area slopes gently downward from altitudes of 430 feet to the shore of the lake. It is usually bordered at the higher altitude by a gravelly and sandy shore line. Other minor ridges of a similar nature extend in a generally parallel direction with the present shore line and at positions intermediate between the higher shore line of the glacial Lake Iroquois and the present shore of Lake Ontario.

From Oswego County westward, and particularly in Wayne and eastern Monroe Counties and in the region immediately south of them, there are numerous lenticular hills (known geologically as "drumlins"). They are also found through the lake plain region at all elevations as far west as Erie County, N. Y. They rise to maximum elevations of 150 feet above the adjacent lowlands and will probably average an altitude of 75 to 100 feet in elevation along their crests. They consist of glacial till and are merely surrounded in the majority of instances by the sedimentary deposits of the several glacial lake occupations of the general territory.

The lower lying land areas, lake sediments in the main, consist of very similar materials reworked by glacial waters and redeposited. The surface of the majority of areas of this character is remarkably flat or uniform in slope in the area which was covered by the glacial Lake Iroquois. The greater part of the sediments of this body of water lie in such positions as to be fairly drained, except in the ex-

treme western portion of the area in Niagara County. As a result only small and scattered occurrences of the soils of the Clyde series are found.

From the vicinity of Rochester, westward nearly to the eastern border of Niagara County, there are rolling plains and low rounded swells which show little or no evidences of having been covered for any length of time by lake waters. These till areas contain no included deposits of soils of the Clyde series so far as the region has been mapped in detail.

The country which rises southward from the 430-foot contour line, the approximate shore line level of the glacial Lake Iroquois, to altitudes of 1,000 or 1,100 feet is varied in its topography. At first the surface does not materially differ from the lower plain. There are larger areas of the rolling swells of till, many drumlins in the eastern section, and a sharp break between the lower plain and the upper as the vicinity of Lockport, N. Y., is approached. There the lower plain is separated from a higher plain of very similar character and soil development by the first evidences of the rock-formed Niagara escarpment over which all of the waters of the Great Lakes pour at Niagara Falls. This escarpment first appears as a low ridge of limestone which becomes more elevated to the westward where it takes the form of cliffs or ridges. At its base lies the old shore line of Lake Iroquois, along its slopes and cliffs the bare rock outcrops, while at its summit the lake sediments again make their appearance and stretch for many miles to the southward, covering the greater part of the country west of the Genesee River and east of the Niagara up to an elevation of 800 feet above sea level. This higher plain is the area which was occupied by glacial Lake Warren and it forms an extension to the east of the glacial lake areas which were developed at about the same geological time in the Maumee Valley of Ohio and the Saginaw Valley of southern Michigan.

The upper plain is much diversified in its surface slopes and drainage features in western New York. The southern portion of Niagara County, the northern part of Erie County, and the adjacent portions of Orleans and Genesee Counties contain large areas of nearly level land with very slight depressions, which have been the location of former swamps, and within which considerable areas of the soils of the Clyde series have been accumulated. Other swampy areas have become the location of deposits of muck and peat.

In the case of all of the larger areas of soils of the Clyde series in extreme western New York the surface is depressed below the general level of the surrounding soils, and the types of this series are poorly drained and darkened by accumulations of organic matter only less in amount than is required to constitute muck soils.

The lake deposits of this section were prevalently fine grained and the heavier soils of the Clyde series are quite extensively developed.

There are also areas in Niagara County where underlying till deposits reached nearly to the surface, but were thinly veneered with lake sediments, and maintained for a long period of time in a partly drained condition. On such tracts there is a scattering of field stones of glacial origin which is unusual with any soils of the Clyde series. Probably a part of these stones have reached their present position through having been brought to the low ridges and stranded by the melting of floating ice. Others have been separated from the till by wave action which redistributed the finer grained materials locally as lake sediment and left the stones in a prominent position at the surface. Such areas give rise to the stony phase of the Clyde loam.

Throughout the entire region of the glacial lake deposits in New York State limestone rock underlies a considerable part of the plain. It has contributed mechanically divided limestone to the glacial till and both directly and indirectly to the lake sediments. Even where both of these classes of material overlie noncalcareous rocks there is a perceptible admixture of limestone fragments of all sizes in both the unstratified materials and the sedimentary deposits. This furnishes the small or large percentage of lime carbonate which is associated with the subsoils, at least, of the majority of the types of the Clyde series.

up to an elevation of 800 feet above sea level. This higher plain is

In extreme western New York, from Dunkirk to the western boundary of Chautauqua County, in the northwestern portion of Pennsylvania, around Erie, Pa., and in northeastern Ohio, around Ashtabula, the glacial lake plain is very narrow, measuring not more than 3 to 5 miles in breadth from Lake Erie southward. Only small areas of the soils of the Clyde series are found in this region.

From the vicinity of Sandusky, Ohio, westward nearly to Fort Wayne, Ind., and thence northeastward to the vicinity of Port Huron, Mich., lies an extensive area which was occupied at several successive stages by glacial lake waters. The oldest of these glacial lakes has been named Lake Maumee. This was succeeded by Lakes Whittlesey and Warren. The latter occupied a portion of the higher lake plain in western New York as well as the lower portion of the glacial lake plain in northwestern Ohio and adjacent portions of Michigan.

It is probable that the waters of these several glacial lakes did not occupy the Maumee Valley for any great period of time, yet it is certain that they were present for a sufficient period to establish very definite shore lines on the landward side. These shore lines

have been traced accurately through northern Ohio, northeastern Indiana, and southeastern Michigan.[1]

The lower limit of the glacial lake sediments which were formed in this basin is at present marked by the shores of Lake Erie and of the St. Clair River, Lake St. Clair, and the Detroit River. This lies at an altitude of about 575 feet above sea level. The highest limits of occupation by the glacial Lake Maumee are found to be approximately 775 feet above tide in the vicinity of Fort Wayne, Ind., about 800 feet in the southeastern counties of Michigan, and ranging from 750 to 800 feet above sea level in north-central Ohio. There is thus a total difference of present elevation of the surface of these glacial lake deposits not exceeding 225 feet. The Maumee Basin thus presents a very gently sloping surface which is inclined from the level of the shore lines toward a central axis extending from Fort Wayne, Ind., to Toledo, Ohio, with a gentle slope toward Lake Erie along the line of this axis. The slopes are so slight over any limited area that it is difficult to determine their direction except by the aid of leveling instruments. The stream-drainage ways are deeply cut along the major streams but follow mere shallow trenches so far as the majority of tributaries are concerned. The Maumee River has cut its channel to a depth of 15 to 60 feet, frequently encountering bedrock. The smaller streams have cut their courses from 10 to 40 feet below the level of the plain.

The general surface of the lake plain in the Maumee Basin is but slightly undulating over the upland between the drainage ways. Low swells and ridges rise to altitudes of 5 to 20 feet above the lowest points in any given locality. There are also low moraine ridges of somewhat greater elevation which probably rose above the level of the ponded lake waters. The Defiance moraine in the extreme northwestern counties of Ohio thus separates all of the basin lying in Allen County, Ind., and a large part of the lake sediments found in Defiance, Paulding, and Van Wert Counties, Ohio, from the remaining area of the Maumee Basin.

Below the highest shore line of the glacial lake waters there are usually two or more other shore lines existing as concentric ridges of gravelly and sandy material frequently separated from each other by sandy loam or loam deposits. Elsewhere through the Maumee Basin the greater part of the surface consists at present of the dark-brown or black clay loam or clay soils of the Clyde series.

The chief exception to this rule is found along the immediate banks of the Maumee River and its principal tributaries where erosion has removed the shallow lake deposits, exposing the underlying till in the form of yellow or brown clay loam soil, classed with the Miami

[1] Glacial Formations and Drainage Features of the Erie and Ohio Basins, U. S. Geol. Surv. Monograph No. XLI. By Frank Leverett.

series. There are included areas of swamp and muck, which occupy a small aggregate percentage of the region. The limestone rock which underlies a considerable proportion of this basin also reaches the surface in the form of local rock outcrop. There are a few small areas where the glacial till is exposed or where it was covered to such a shallow depth by the glacial lake waters that distinctive lake or swamp deposits were not formed. It is probable, however, that 75 per cent of all of the soils found within the area of the Maumee Basin have been formed, at least at the surface, through the deposition of lake sediments and through an unusual accumulation of organic matter under succeeding swampy conditions. Frequently the subsoil and deeper material consist of a gravelly glacial clay, classed as till by some authorities and as glacial lake material mixed with ice-borne fragments by others.

The northern extension of the glacial lake deposits in the Maumee Basin was undoubtedly connected along the southwestern shore of Lake Huron with a similar area which surrounds the present Saginaw Bay in east-central Michigan. The shore-line features are continuous, the sediments deposited are almost identical, and the lake plain extends as a narrow border along the eastern shore of the "thumb" of Michigan.

The extensive lake plain which lies to the south and west of Saginaw Bay was occupied by another glacial lake, which has been called the glacial Lake Saginaw. It is certain that its upper stages were continuous and contemporaneous with the upper stages of the glacial lake waters of the Maumee Basin.

The highest beach level formed by this lake in the Saginaw Basin lies at an elevation of about 850 feet above sea level in the vicinity of Flint, Mich. This is at an altitude of about 260 feet above the waters of Saginaw Bay, and the present area in the Lake Saginaw Basin thus possesses a fall of approximately 250 feet from the old shore lines to the present shore line. The concentric beaches around the margin of this embayment lie at several levels and are usually marked by sandy and gravelly deposits, between which sandy loam material prevails. The central portions of the area are somewhat more undulating than in the case of the Maumee Basin and considerable areas are occupied by low morainic ridges whose crests were apparently about at water level during the later stages of glacial lake occupation. It appears that extensive deposits of sandy and gravelly material were formed within the limits of the lake basin as delta material from the streams which flowed into Lake Saginaw, both from the glacial ice, forming the northeastern boundary of the lake and from the exposed till upland forming its border to the south and west.

While there are very extensive deposits of unquestioned lake sediments within the area of the glacial Lake Saginaw, there are also numerous large areas where the glacial till remains uncovered by glacial lake materials or is so thinly covered that only portions of the present surface may be confidently ascribed to glacial lake deposition. Some of these deposits, because of the large amount of partially decayed organic matter in the surface soil and because of their evident previously swampy condition, are more closely related to the soils of the Clyde series than to any other group. Others, not so marked, belong to other soil series. The glacial outwash materials and many of the beach line deposits do not contain sufficient organic matter to give them the characteristic dark color of the Clyde soils.

Because extensive water-laid glacial moraines are closely associated with and partly covered by the glacial lake deposits some members of the Clyde series are found to be gravelly or stony in the Saginaw Lake area.

In general the surface of the Lake Saginaw area is undulating to gently rolling, although considerable areas, extending northeast from Saginaw along the south shore of Saginaw Bay, are very flat and unrelieved. In consequence, a considerable proportion of this glacial lake area is fairly well drained through the deep-cut channels of the larger streams. Other portions, because of level topography and lack of natural stream ways, have remained swampy until recent years.

Another glacial lake area of limited extent was formed in southwestern Michigan, northern Indiana, northeastern Illinois, and southeastern Wisconsin around the southern end of Lake Michigan. This was known as the glacial Lake Chicago. The majority of the deposits within this area do not form soils which are included in the Clyde series. However, in a narrow belt extending along the western shore of Lake Michigan from the vicinity of Racine, Wis., nearly to Chicago, Ill., the soils of the Clyde series occupy the greater proportion of the old glacial lake bed. In this area the soils of the Clyde series are found from the shore line of Lake Michigan to altitudes of 60 feet above its present level, at which elevation the shore line of the ancient glacial lake stood. This belt of territory ranges from 2 to 5 miles in width. The highest land within it frequently lies near to the present lake shore, declining gently inland for a distance of 1 or 2 miles and then rising rather sharply to the old shore line. At the higher elevations more sandy soils are found, while in the depression the soils of the Clyde series prevail.

Surrounding Green Bay and Winnebago Lake and extending southwestward past Fond du Lac, Wis., occurs another area which was occupied by glacial lake waters. The highest shore line which bounds this area lies at a level of 800 to 820 feet above sea level, or 220 to 250 feet above the present level of Lake Michigan. In general, the surface of the lake sediments in this area is level or gently undulating, although ridges of till rise above the lower lying glacial lake material. As in the case of the western New York areas and the Saginaw Bay area, other glacial lake sediments occupy considerable areas within this region, yet the lower, more level, and poorly drained sections where organic matter has accumulated extensively are occupied to some extent by soils of the Clyde series. As in the case of the majority of the other localities where soils of this series are found, limestone rock underlies a considerable proportion of the glacial lake embayment around Lake Winnebago and Green Bay. It has been reworked to some degree into the glacial till and into the glacial lake sediments derived from the till.

It is probable that an examination of the Upper Peninsula of Michigan will show small areas of the Clyde soils lying at the lower levels around Lake Huron and along the southern shore of Lake Superior. The necessary conditions of local calcareous rock, of glaciation, and of the deposition of glacial lake sediments followed by swampy conditions after the withdrawal of glacial lake waters all exist in the eastern end of the northern peninsula of Michigan.

The occurrences of the Clyde series thus far outlined all lie within the larger glacial lake basins surrounding the present Great Lakes. In addition there are hundreds of smaller glacial lakes which existed in the upland areas, outside of these larger basins, in western New York, southern Michigan, northern Indiana, and southern Wisconsin particularly. In many instances these small glacial lakes have become drained or have been partly filled with accumulations of both mineral and organic matter. In such instances smaller areas of the different soils of the Clyde series have frequently been formed. Such is the case in many of the southern counties of Michigan and of the southeastern counties of Wisconsin.

Another characteristic mode of occurrence of the soils of the Clyde series is found along the old glacial drainage lines through which the ponded waters of large and small glacial lakes found their outlet across the divides. In many instances these drainage channels now exist as broad river valleys cut through the glacial till where the present streams are bordered by one or more broad, flat, and frequently poorly drained river terraces. Wherever drainage has been sufficiently obstructed to give rise to temporary swamp conditions there has been considerable accumulation of swamp vegetation, contributing organic matter to the surface soil. In some instances this

accumulation has been sufficient to constitute a normal soil rendered dark brown or black at the surface. In the latter cases considerable areas of different soils of the Clyde series have been formed.

The largest single area of this description occurs in northwestern Indiana and northeastern Illinois along the banks of the Kankakee River. From the southern boundary of Michigan to Will County, Ill., this river is bounded by a level terrace area which was probably formed as the bottom of a local glacial lake but which has since been drained by the cutting down of the lower reaches of the Kankakee River. The present land surface lies at an elevation from 10 to 30 feet above the normal level of the river. The area constituted a vast swamp in the early days, but has been partially drained and occupied. Its surface is only relieved by low ridges of sand which in many instances resemble lake-shore deposits but in other cases are evidently sand dunes.

A considerable part of the terraces along the Kankakee River is occupied by the more sandy members of the Clyde series. Other portions consist of muck and peat, of sand dunes, and of undrained swamps.

There are many other instances where smaller areas of soils of the Clyde series are found within the old glacial terrace deposits along the courses of streams once occupied by a greater volume of water than at present. Certain of these areas of the Clyde series are found far to the south of the glacial lake areas within which the greater part of the Clyde series soils occur.

Numerous small areas of soils of the Clyde series are also found in depressions throughout the glaciated uplands of western Ohio and northern Indiana.

TYPE DESCRIPTIONS.

CLYDE SAND.

The Clyde sand has only been encountered in the southern peninsula of Michigan, where five soil survey areas have included portions of this type. By far the largest area, amounting to more than one-half of the total, occurs in Allegan County, Mich. Here the type occupies 38,600 acres, while the total area surveyed in the State amounts to 67,400 acres. It is probable that the extension of soil surveys in this general region will show a much larger total area of the type, occurring in low-lying and poorly drained locations where sandy glacial outwash was accumulated under ponded and swampy conditions.

The surface soil of the Clyde sand to an average depth of 12 inches or more consists of a medium to fine grained, black, sandy loam, well supplied with partly decayed organic matter. The subsoil varies

in the different areas from a gray or white sand to a gray silty clay. In almost all cases the surface soil is immediately underlain by a layer of gray or white sand of medium to coarse texture to a depth of 2 or 3 feet from the ground surface. This is, in turn, underlain by a heavier and more silty or claylike deep subsoil which is very retentive of moisture.

Not infrequently a small amount of fine gravel is found, intermingled with both the surface soil and subsoil. It does not usually interfere with the cultivation of the soil and is not so abundant nor so generally present as to make any appreciable difference in the relationships of the soil type to moisture.

The Clyde sand is always found in level tracts which are depressed below the general level of the surrounding uplands and in positions where either glacial outwash or later soil wash from sandy upland areas has accumulated under conditions of poor drainage. There are no elevations or irregularities of surface which would interfere with cultivation. Frequently the areas occupied by the Clyde sand still receive wash from higher lands, and they also receive a considerable amount of seepage water from adjacent porous soils of greater elevation.

Practically all areas of the Clyde sand are found to be in a swampy condition when first occupied, and many areas have remained unreclaimed by artificial drainage. As a result of this condition large amounts of vegetable matter in a partly decayed state have accumulated in the surface soil, rendering it black in color and loamy in texture. Similarly the drab or gray color of the subsoil is an indication of poor natural drainage. The excess water held in the subsoil has excluded the air, and there has been little or no weathering and oxidation of the iron-bearing minerals of the subsoil. Where drainage has been partly established the subsoil colors are tinged with yellow or brown.

Wherever the Clyde sand has been occupied for the more intensive forms of agriculture it has been necessary to establish open ditches for the outlets of extensive tile underdrains or in connection with smaller open farm ditches. In its natural condition the Clyde sand supports a thick growth of water-loving trees and of swamp grasses. In such localities its chief economic use is as pasture. Only when artificial drainage has been installed is the type well suited to crop production.

Where the Clyde sand has been properly drained it has been successfully occupied for the production of the general farm crops, of which the yields are moderate. Corn is one of the most extensively grown and important crops. The large amount of organic matter in the surface soil, the ease with which a good moisture supply is maintained, and the easy tillage of this soil tend to make it one of

the best of the sandy soils for corn production. In fact, its position and natural drainage features combine to retain more soil moisture than would otherwise be possible in such a porous soil. It ranks more nearly with the sandy loam upland soils than with sand soils for these reasons. The general average of corn yields upon the Clyde sand ranges from 20 bushels per acre, usually where drainage is defective and the stand is reduced by excess moisture, to 35 bushels per acre or more where drainage has been established and the organic matter content of the surface soil has been carefully maintained through the application of stable manure. Corn is grown both for the grain and for silage, and the yields of silage range from 8 to 10 tons per acre. While the type is a fairly good corn soil it is not so well suited to this crop as are the heavier members of the series.

Oats are also grown in regular rotation with corn and grass. The large amounts of organic matter in the surface soil and the high moisture content tend toward an excessive growth of straw, and this is frequently weak and unable to support the grain crop to maturity. The yields are frequently reduced through losses from the lodging of the grain. Where drainage is fully established good yields are secured. The yields of oats range from 25 to 40 bushels per acre. Sometimes the partly matured crop is cut for hay when the lodging is so marked as to indicate that grain production would be impossible or unprofitable.

Hay constitutes one of the most extensively grown crops upon the Clyde sand. Even where the drainage is not sufficiently established to insure good grain crops it is adequate for the growing of timothy or of mixed timothy and alsike clover. Areas of this character are seeded down and frequently left in grass for a period of three to five years or more. Hay is cut during the earlier years of the seeding, and the land is pastured when the hay yield falls below 1 ton per acre. In other wetter areas the wild grasses are cut for hay or utilized for pasture. In the cultivated fields the yields of mixed hay range from 1 to 1½ tons per acre. The average yield of the wild grasses cut for hay is not over 1 ton per acre. The pastures upon this soil are usually well maintained during the dryer months of summer because of its low-lying and partially drained condition. Grass production upon the Clyde sand should be one of its chief uses where it is not so situated nor so well drained as to render it available for the growing of the more intensely farmed crops.

Wherever the drainage conditions in the different areas of this soil have been perfected the Clyde sand is especially well adapted to the growing of special crops. When markets are accessible these crops should constitute the chief dependence of agriculture upon this soil. Sugar beets are successfully grown upon the higher lying and better drained portions of the type, giving yields of 10 tons or more per

acre. The sugar content is high and this soil is probably the best sandy soil upon which to grow the crop. Care should be exercised to provide perfect drainage, and to maintain the organic matter content of the soil. The beets should be grown but one year upon any given field, as crop rotation is essential to obtaining the best yields.

Early Irish potatoes give fair yields of tubers of good quality. The yields range from 100 to 150 bushels per acre. In growing the potato crop perfect drainage is essential to success, as otherwise danger from blight and scab is great. The use of large quantities of high-grade commercial fertilizer is requisite. The most successful potato growers use as much as 500 to 1,000 pounds per acre of a fertilizer which analyzes about 2 to 3 per cent of nitrogen, 8 to 10 per cent of phosphoric acid, and 7 to 9 per cent of potash, derived preferably from sulphate of potash. Frequent shallow cultivation is required during the earlier part of the growing season. The spraying of the crop to reduce damage from blight is not common, but should be generally adopted upon this low-lying and moist soil type.

In the vicinity of some of the larger cities, where the local market is good, other market-garden crops are grown upon the Clyde sand. Cabbage, onions, cauliflower, tomatoes, cucumbers, and string beans are thus produced in the vicinity of Saginaw, Mich., and the crops obtained are very profitable. Only a small area of the Clyde sand has yet been utilized for such crops and the extension of market gardening upon the type is dependent chiefly upon increased market outlets rather than upon the development of unused areas of the soil. Many thousands of acres may be used for these intensively farmed crops when the demand arises. A field of onions on the Clyde sand is shown in Plate I, figure 1.

The Clyde sand may be characterized as a soil fairly well suited to the growing of general farm crops where drainage has been installed, for pasturage where drainage is only partial, and for the growing of market garden crops and sugar beets where the local market for these crops exists and where the type has been completely drained.

There are thousands of acres of this soil which are but partially reclaimed at present and which constitute a reserve of easily worked, special-purpose farm land still awaiting utilization.

In general the farm equipment upon the Clyde sand does not differ materially from that of the general region where it is found. The market-garden farms are usually of rather small area and are frequently only equipped with a small residence and with sheds or small barns for the housing of work stock and tools. The general farms upon the type are usually improved with the larger house and the large barns common to the grain and dairy farms of

the Central States. The type is susceptible of efficient tillage with rather light teams and tools, and these are used for the more intensive forms of cultivation. In fact much of the work of the market-garden farms is performed by hand after the land has been fitted by horse labor for the planting of the various crops.

CLYDE GRAVELLY SAND.

The Clyde gravelly sand has only been encountered in two areas, both occurring in the southern peninsula of Michigan. Its total extent amounts to only 24,656 acres as mapped to the present time. Its most characteristic occurrence is in the vicinity of Saginaw, Mich., where it is found along old beach lines of the glacial Lake Saginaw, and in low slopes along bases of the surrounding glacial hills. It is found in Allegan County, Mich., in the form of low, rounded gravelly hills and as the chief soil of the low terraces which border the Kalamazoo River in that county.

The surface soil of the Clyde gravelly sand to an average depth of about 10 inches is a medium-textured, dark-brown, loamy sand, marked by the presence of a considerable proportion of medium to fine gravel. The subsoil is rather coarse, incoherent gravelly sand which is either underlain by gravel, as in the case of the river terraces, or grades into coarse sand and gravel at a depth of about 2 to 3 feet. Usually clay is found at a depth of 4 to 6 feet.

The surface soil always contains a sufficient amount of partly decayed organic matter to give it a characteristic dark-brown or nearly black color and to render it somewhat loamy. The type, as a whole, is fairly well drained owing to its sloping position on upland areas and to the near presence of drainage ways on the river terraces.

The general farm crops of the region where it occurs are chiefly grown upon the Clyde gravelly sand. Corn produces fairly good yields ranging from 25 to 35 bushels per acre. It is found necessary to use stable manure freely upon this rather porous soil in order to secure the larger yields. It is not a typical corn soil and other crops are better suited to it.

Among the small grains both rye and buckwheat produce fair yields. They are more commonly grown than either wheat or oats and are better adapted to this soil. Rye yields 12 to 15 bushels per acre, and buckwheat 15 to 20 bushels. Oats give only small yields in normal years, owing to the fact that the soil does not retain a sufficient amount of moisture to supply the needs of the crop at the time of the formation of the grain. Either rye, which matures earlier, or buckwheat, which is a late summer crop, should be preferred to oats.

While there is some difficulty in securing a good seeding of mixed grasses, clover gives a good seeding and excellent yields. Mixed hay produces an average of about 1 ton per acre, while clover alone yields from 1 to 1½ tons per acre at the first cutting with a possible second crop for seed. Red clover is chiefly grown, although the alsike clover is also well suited to production on this soil.

Some difficulty is experienced in securing a good stand of sugar beets and they are grown only to a very limited extent upon the Clyde gravelly sand. Beans give fairly good yields.

The Clyde gravelly sand is so thoroughly drained that the longer-growing field crops are not so well adapted to production upon it as the early truck and small fruit crops. As yet, these are scarcely grown at all since the chief areas of the type, as found, are not especially well situated with regard to markets. Considerable areas of the type are not occupied agriculturally.

CLYDE FINE SAND.

The Clyde fine sand has been encountered in eight different soil-survey areas, located in New York, Indiana, Illinois, and Wisconsin. A total area of 74,048 acres has been mapped of which 68,480 acres are found along the terraces bordering the Kankakee River in Newton County, Ind., and Will County, Ill. The other areas are small and of little agricultural importance.

To an average depth of 10 inches or more, the surface soil of the Clyde fine sand is a dark-gray to black, medium to fine sand. It is always heavily charged with partly decayed organic matter and not infrequently grades into included areas of peat. In such cases the organic matter is found to extend in large quantity to depths of 3 feet or more. In other instances, near the margins of sandy islands and bars, which rise above the general level of the Clyde fine sand, there are bordering areas where the dark-colored surface soil is only about 4 to 6 inches deep. In some localities over the more level portions of the type, sandy areas with a shallow covering of organic deposits are also found. The subsoil is a gray sand which varies from dark color near the surface to a lighter gray or ash color at greater depths. The subsoil is sometimes mottled with brown or yellow stains. At the greater depths the sandy subsoil frequently becomes somewhat compact and sticky through the presence of larger proportions of silt and clay. The type is stone free in both soil and subsoil and even gravel is of rare occurrence.

In all of the smaller areas of its occurrence the Clyde fine sand occupies small depressions within the area of other sandy soil types and owes its existence to the deposition of large amounts of organic matter where natural drainage was deficient. These areas mark the

former existence of small glacial lakes, ponds, and succeeding swamps within upland areas or associated with other glacial lake deposits. In the chief occurrence along the terraces of the Kankakee River, in northern Indiana, the Clyde fine sand has been formed as a sandy deposit of the glacial predecessor of the present river, whose flood plain was many miles in width and probably consisted of ponded glacial waters at one or more stages of the development of the drainage way. It would be unusual to encounter such a large area of such uniformly assorted sand in the channel of any very active stream and it is more probable that the present channel represents stream excavation followed by the ponding of water and the deposition of the sand as sorted material derived from a variety of sources and laid down to some extent by the tributary streams as well as by the major stream which later occupied the valley.

The Clyde fine sand, in Newton County, Ind., occupies a strip of territory south of the Kankakee River, having a breadth of 10 to 12 miles. It extends across the boundaries of the county both to the east and to the west and a similar strip of soil is found on the north bank of the river. The area surveyed in Newton County comprises only a small proportion of the total area of the type as it occurs along the Kankakee River.

Near the river the surface of the Clyde fine sand lies at elevations of only 5 to 10 feet above the normal stream level. There is a gentle rise away from the river which rarely amounts to more than 1 or 2 feet per mile and the appearance of the river terrace is that of a very level plain which is only relieved through the irregular occurrence of sandy ridges, rising in the form of old shore lines or sand dunes above the general level. These have altitudes of 10 to 30 feet above the surrounding plain. It is along the flanks of these ridges that the Clyde fine sand reaches its highest elevations above the river and where it was best drained under natural conditions. Shallow depressions are also found in the plain within which the swampy conditions have so long persisted that accumulations of peat or muck were formed, having a depth of a few inches to many feet. Otherwise the broad, nearly level river terrace is occupied chiefly by the Clyde fine sand.

For a long period of time, during the settlement of the region, the plain occupied by the Clyde fine sand remained in a swampy and almost impassable condition. More recently extensive ditches have been opened by the counties involved and into these the local farm drainage is led. In the majority of instances the drainage is still accomplished by open ditch, but a beginning has been made in the tile underdrainage of the land. This should be extended over the entire area, since it is the only permanent and completely satisfactory

method by which these lands may be brought to their full producing capacity.

Drainage still remains so imperfect over considerable tracts that the farm buildings are located upon the sandy elevations which rise above the general level of the plain. Many local swamps persist and the peat areas have been but recently drained. Both from the standpoint of profit and of health drainage should be extended and rendered more complete.

The crop adaptations of the Clyde fine sand vary considerably in the different areas where it has been encountered. In the most extensive area, in Newton County, Ind., the crop uses vary chiefly with the proportion of organic matter found in the surface soil and with the depth of the dark-colored surface soil. Those areas in which the organic matter content is rather small are chiefly devoted to pasturage, while the areas well supplied with vegetable remains to a considerable depth are used for the production of general farm crops.

Corn is the principal tilled crop grown. It is reported that in the early days of the occupation and cultivation of this soil the yields secured were as high as 50 bushels per acre. It is now estimated that the average yield is about one-half of this amount. Present yields range from 10 to 35 bushels per acre. Corn is grown for one or more years and the land is then seeded to a small grain crop, almost always to oats. Oats yield from 20 to 30 bushels per acre. In the usual rotation the field is next seeded to grass. Timothy is commonly sowed alone as clover is likely to be winter killed on the level and partly drained land. It is probable that redtop and meadow fescue could be added to the seeding mixture with profit where it is intended to cut the hay for home feeding and to follow several years of hay production by the pasturing of the fields before they are again plowed for corn. It is also certain that alsike clover may be profitably seeded with the grasses where the land is fairly well drained.

When clover is to be seeded the Clyde fine sand would be greatly benefited by the application of 1 to 2 tons per acre of finely ground limestone rock. This should be applied when the seeding to grass is made, usually with the seeding of the oat crop. It would also benefit both the oat crop and the grass seeding to apply finely ground raw phosphate rock at the rate of not less than 500 pounds per acre at the time of oat seeding. It has been demonstrated, also, that all crops are greatly benefited through the application of muriate of potash or kainit to such soils as the Clyde fine sand, especially where the content of organic matter in the surface soil is unusually high.

Proper liming and fertilization should greatly increase the yields of all of the general farm crops. Where possible, stable and yard manure should be applied to the corn ground.

Where the Clyde fine sand has been thoroughly well drained it has produced excellent crops of Irish potatoes. The average yields are estimated at 125 to 200 bushels per acre.

Rye is sometimes grown as a winter grain crop and serves well as a nurse crop for timothy and other grasses. It gives yields of grain which range from 10 to 20 bushels per acre.

The grasses usually seeded give yields of hay which range from three-fourths of a ton to 1½ tons per acre. In addition, large areas of marsh hay are annually cut, giving yields of approximately 1 ton per acre of rather coarse hay.

By far the greater part of this soil type is still used for natural pastures. Even in areas where drainage is only partially established and the intertilled crops and timothy may not be successfully grown, the wild grasses furnish an excellent grazing for a considerable portion of the year. Frequently the herds are grazed during the summer months and fed through the winter on marsh hay cut on adjacent areas and stacked on well-drained land. Such a field of marsh hay is shown in Plate I, figure 2. As a result of the large areas given to hay growing and pasturage there is a considerable live-stock industry conducted on the Clyde fine sand. This takes the form of the growing and fattening of beef cattle chiefly, although a small amount of dairying is also conducted near shipping points or local markets. Some hogs are fattened as an adjunct to the other forms of stock raising.

In other areas the Clyde fine sand is chiefly undrained and unoccupied for any other uses than pasturage and timber lot. Some small areas, near to city markets, have been drained and used for market gardening. The small fruits, particularly strawberries and raspberries, give good yields, while such crops as cabbage, onions, and celery may be grown to advantage where the organic matter is abundant in the surface soil and the depth to subsoil is not less than 12 to 18 inches. Table beets and turnips may also be grown. In the case of the vegetables the liming of the soil is requisite to the best results. This is particularly true of cabbage, onions, and beets. The latter furnish one of the best indicators among vegetable crops of the lime requirements of a soil. They are not grown to advantage upon any soil that is badly in need of lime and the yields are greatly increased by the abundant use of lime, either as ground limestone or marl or as quicklime, slaked, and applied some time before the seeding of a crop.

For the improvement of crop yields upon the Clyde fine sand better drainage is the first requisite. This should usually be followed by the liming of the land and the use of rock phosphate and muriate of potash or kainit. Wherever stable manures are available they

should be applied to the intertilled crops in general farm practice and to all of the crops grown in market gardening or small-fruit production.

Many thousands of acres of the Clyde fine sand are utilized only for pasturage or the cutting of wild grasses. Most of the remaining area is used principally for a type of mixed general farming and stock growing. Only small areas are used for the more intensive forms of market gardening and small-fruit cultivation. Wherever markets for the products are available, the type is far better suited to the latter uses than to general farming.

The farm equipment of the Clyde fine sand is not materially different from that of other areas in the general farming section of the north-central States. It usually consists of a frame dwelling and of large or small barns, depending upon whether the chief interests of the farm center in cattle feeding or in the production of crops for sale. Large teams and heavy machinery are commonly employed in the tillage of the type.

CLYDE SANDY LOAM.

The Clyde sandy loam has been encountered in seven soil-survey areas, located in Indiana, Michigan, Pennsylvania, and Wisconsin. A total area of 127,296 acres has thus far been mapped. By far the largest proportion of this area has been encountered in the Saginaw Bay region in the southern part of Michigan. In fact the other areas of its occurrence are small and scattered.

The Clyde sandy loam to an average depth of from 8 to 12 inches is a dark-gray, brown, or almost black medium-textured sandy loam. The surface soil contains varying amounts of organic matter. In the lower-lying locations, in all depressions, and where drainage has been seriously obstructed there is a considerable accumulation of dark, mucky organic matter in the surface soil. Upon slopes and somewhat higher ridges, which frequently occur through the type, organic matter is present in less proportion and the surface soil becomes gray or light brown in color. In almost all cases the surface soil grades downward into a medium to fine sandy loam, which is usually darker just beneath the surface soil, but becomes gray or mottled gray, drab, or yellow at greater depths. At a depth of 3 feet or more the subsoil becomes a sticky, somewhat sandy clay.

The characteristic surface features of the Clyde sandy loam vary somewhat in the different localities where it has been found. This arises from the fact there have been some slight differences in the method of formation of the different areas of the type. In Greene County, Ind., the surface of the Clyde sandy loam is almost absolutely level and depressed below the upland areas in the por-

tion of the county where it occurs. This arises from the fact that the Clyde sandy loam was probably formed as a somewhat sandy outwash when glacial waters were discharged down the present drainage ways of the Eel and White Rivers. For a time at least these waters were so ponded as to form a local glacial lake within which sandy outwash material was deposited. This was mingled with a considerable amount of organic matter from the vegetation that grew in the swampy areas which ultimately resulted. In the majority of the other areas where the Clyde sandy loam occurs the surface is gently undulating to somewhat ridged. In the Saginaw area, Michigan, the Clyde sandy loam represents areas of sandy glacial till or water-laid moraines where glacial material was deposited either through glacial outwash or at such low levels that shallow lake waters covered a considerable proportion of the distinctively glacial till. In such regions all of the lower-lying portions of the Clyde sandy loam were formed under water-logged, swampy conditions, and a large amount of organic matter was deposited under these circumstances.

The local drainage conditions for the Clyde sandy loam vary considerably. In northern Greene County, Ind., the area now occupied by this soil type constituted extensive marshes in the earlier days, and the dredging of large ditches was essential before any portion of the type could be reclaimed and used for agricultural purposes. In the Michigan areas where the Clyde sandy loam occurs extensively it was frequently the case that the higher lying and better drained portions of the type could be immediately used for agriculture without the installation of extensive drainage works. However, the lower lying and depressed portions of this soil have been considerably improved for agricultural occupation by the digging of short local ditches and occasionally through the installation of tile drains. In almost all cases the producing power of the soil is decidedly increased where tile underdrainage is practiced.

The Clyde sandy loam constitutes an excellent general farming soil, except where it still exists under swampy conditions. Corn is the principal crop grown upon this soil, and the yields range from 35 to 40 bushels per acre under average conditions, with yields attaining 80 bushels per acre under particularly favorable conditions of drainage and of long growing season. Oats are grown extensively, giving yields which range from 25 to 40 bushels per acre. Hay also gives excellent yields, ranging from 1 to 1½ and sometimes as high as 2 tons per acre. Timothy alone is grown or timothy mixed with some of the clovers, usually the alsike or red varieties. In Michigan a considerable amount of clover is grown alone. The first cutting is saved for hay. Frequently the second cutting is allowed to mature

seed and fair yields of clover seed are obtained. This is shown in Plate II, figure 1. These constitute the principal general farm crops produced upon the type.

The Clyde sandy loam where properly drained also constitutes an excellent soil for the production of Irish potatoes. The late or staple crops are principally grown, although near good markets an early market-garden crop is also produced. The yields range from 80 to 150 bushels per acre under normal conditions, but yields in excess of 200 bushels per acre are reported. Beans constitute another special crop extensively grown in the Michigan areas upon the Clyde sandy loam. Wherever the type is well drained, either naturally or artificially, good yields of beans are produced, ranging from 12 to 25 bushels per acre. Sugar beets are another crop which is grown to fair advantage upon the Clyde sandy loam. The yields range from 7 to 15 tons per acre, with an average of about 10 tons. Wheat, barley, and alfalfa are all grown to a small extent upon this soil type. Alfalfa may only be grown where artificial underdrainage has been installed. Otherwise the crop is likely to make a good stand for one or two years and then, when the tap root of the alfalfa reaches the poorly drained subsoil, difficulty is experienced in maintaining a stand.

The use of the Clyde sandy loam for the production of special crops has not been extensively undertaken, except in the case of beans, sugar beets, and potatoes. The type is also well adapted by its physical characteristics and its drainage conditions to the production of onions, cabbage, celery, beets, and turnips as market-garden crops. Locally tomatoes have also been grown to advantage, giving returns approximating $100 per acre. It is probable that, as the markets are developed and transportation facilities are extended large areas of the Clyde sandy loam, wherever it is found, will be utilized for special crop production in conjunction with general farming over the remainder of the type.

The better drained areas of the Clyde sandy loam in both the Alma area and the Saginaw areas in Michigan are particularly well suited to the growing of certain orchard fruits. For quinces, pears, and plums there is probably no better soil type in the areas mentioned. Many varieties of apples are fairly well suited to production upon the higher lying and naturally better drained portions of the type. Strawberries and the cane fruits may also be grown.

In all cases the Clyde sandy loam would be considerably benefited by the installation of additional tile underdrainage. In fact, imperfect drainage in the lower lying and depressed portions of the type constitutes the chief difficulty in producing large crop yields. It is a condition which must be remedied before the more intensive forms

of agriculture, such as fruit growing and market gardening, may be successfully undertaken.

CLYDE STONY SANDY LOAM.

The Clyde stony sandy loam has only been encountered in the soil survey of the Saginaw area, Michigan, where this type covers an area of 8,000 acres.

The surface soil of the Clyde stony sandy loam is a dark-brown, medium-textured, gravelly sandy loam which has a depth ranging from 18 to 24 inches. This is underlain by a gray sandy loam or a mottled brown clay loam which contains a small amount of gravel. The most notable characteristic of the type is the presence of bowlders strewn in large numbers over the surface and occurring less abundantly in the subsoil. These bowlders are chiefly of granite and range in size from large rounded gravel to angular fragments 2 or 3 feet in diameter. It has been found necessary in bringing this soil under cultivation to remove the larger cobbles and bowlders, which are either piled in heaps in the field or else are removed and used in the construction of farm buildings and of fences around the fields. Wherever this has been done the surface soil is left in good tillable condition. A few areas of the type are almost entirely free from gravel and stone.

The Clyde stony sandy loam constitutes small, level, depressed areas occurring within the glacial moraine. The type is naturally fairly well drained, but the smaller areas receive seepage waters from the adjacent higher lands. There is frequently no natural drainage outlet or only a sluggish streamway, partly obstructed by rank vegetation.

The greater part of the soil type has been improved and brought under cultivation. It is used chiefly for general farming purposes. Corn yields from 25 to 40 bushels per acre, oats from 20 to 50 bushels, wheat from 15 to 20 bushels, and beans from 10 to 12 bushels per acre. Hay gives excellent yields, ranging from 1 to 1½ tons per acre. Sugar beets are grown in a small way, giving yields of 7 to 15 tons per acre. Irish potatoes are also grown in small acreages. This type practically constitutes a phase of the Clyde sandy loam, which is distinguished from it through the considerable amount of stone and gravel occurring in both soil and subsoil.

CLYDE FINE SANDY LOAM.

The Clyde fine sandy loam has been encountered in 13 different soil-survey areas, located in 5 different States. The total extent of the type thus far mapped amounts to 147,456 acres. The larger part of this type occurs in the Saginaw area, Michigan, in Will County, Ill.,

and in some of the areas in New York, notably in Niagara and Jefferson Counties.

The surface soil of the Clyde fine sandy loam, to an average depth ranging from 9 to 12 inches, is a dark-gray, dark-brown, or almost black fine sand or fine sandy loam. The subsoil is a brown, gray, or yellow fine sandy loam extending to a depth of 2 feet or more, where it frequently overlies a brown or drab clay. Both the soil and subsoil are entirely free from gravel and stone.

In some of the larger areas where the Clyde fine sandy loam has been encountered, especially in Niagara County, N. Y., and the Saginaw area, Michigan, the surface of the type is slightly undulating to gently rolling in topography, and is billowy in general appearance from the occurrence of large numbers of low ridges and narrow depressions between them. There are many level areas even in connection with this billowy topography. The Clyde fine sandy loam is frequently found also in the form of long, low, narrow ridges along the margins of the areas where other soils of the Clyde series are extensively developed. It is probable that in the majority of instances these low ridge areas represent old beach lines or shallow water deposits where the wind has built up a considerable deposit. In some instances the Clyde fine sandy loam represents areas where streams have flowed into the old glacial lakes and developed low, nearly flat deltas. In all cases there has been more or less wind action in piling up the surface soil.

The low ridges which occur within the limits of the Clyde fine sandy loam are fairly well drained in their natural condition. The more level areas and the depressions between these ridges are frequently poorly drained. This is true also of the small areas of the Clyde fine sandy loam associated with the other soil types in upland areas. In nearly all instances the better drained portions of the Clyde fine sandy loam show a light-brown or yellow coloration of the surface soil, owing to the fact that not as much organic matter has been deposited in these locations as in the hollows and depressed areas which have not been as well drained.

The lower lying portions of the type are not only poorly drained because of their depressed position, but in many instances there is some seepage of water from adjacent, more elevated land areas. All of these depressed areas require artificial drainage to fit them for farming. In fact, in a number of the soil-survey areas where the type has been encountered it is still in timber or is used only for pasturage or some other extensive form of agricultural occupation. Yet a considerable proportion of the Clyde fine sandy loam is fairly well drained in its natural condition and can be occupied for the production of general farm crops or for special fruit and market-garden crops.

FIG. 1.—ONIONS GROWN ON CLYDE SAND, ALLEGAN COUNTY, MICH.

FIG. 2.—MARSH HAY CUT ON CLYDE FINE SAND ALONG THE KANKAKEE RIVER IN INDIANA.

FIG. 1.—HARVESTING SECOND-CROP CLOVER FOR SEED. CLYDE SANDY LOAM, NEAR SAGINAW, MICH.

FIG. 2.—TOMATOES GROWN IN YOUNG PEAR ORCHARD ON CLYDE FINE SANDY LOAM, NIAGARA COUNTY, N. Y.

There is a considerable diversity in the uses to which the different portions of the Clyde fine sandy loam have been put in the production of crops. In almost all of the more western areas the general farm crops alone are produced. Thus in the Saginaw area, Michigan, where more than 39,000 acres of the type have been encountered, corn is one of the principal crops grown. The yields range from 20 to 40 bushels per acre. Oats constitute the principal small grain, giving yields of 30 to 50 bushels per acre. Beans are extensively grown, yielding from 10 to 25 bushels per acre, with an average approximating 15 bushels. Hay is also an important crop. Timothy and clover give yields of 1 to 1½ tons of hay per acre. Sugar beets yield 10 to 12 tons per acre. Chicory is also grown to some extent, the yields ranging from 7 to 12 tons per acre.

In Niagara County, N. Y., where an area of nearly 15,500 acres of the Clyde fine sandy loam has been encountered, the soil type is recognized as the best truck soil. This use is shown in Plate II, figure 2. It is extensively planted to cabbage, tomatoes, cucumbers, and potatoes as truck crops, while peas and beans are grown both as truck crops and for sale to the canning factories, which are numerous in this area. A considerable proportion of the type is thus utilized. In this area the general farm crops are also grown. Corn yields from 30 to 60 bushels per acre. A small amount of wheat is grown, giving fair average yields. Oats constitute the principal small-grain crop, with yields ranging from 25 to 50 bushels per acre. Navy beans and hay are also grown.

It is probable that wherever market facilities are afforded the Clyde fine sandy loam could best be developed as a special market-garden and small-fruit soil. It is well suited to the production of a considerable range of market-garden crops, while strawberries and cane fruits are grown to advantage. Wherever the type is well drained the orchard fruits may also be grown.

THE CLYDE LOAM.

The Clyde loam is the most extensive type which has thus far been mapped in the series. It has been encountered in 19 different soil-survey areas located in 4 different States, and an aggregate area of 565,676 acres has been mapped. It occurs to a limited extent in western New York, and in extensive areas in the Southern Peninsula of Michigan, in northern Indiana, and southern Wisconsin. It is probable that other large areas of the Clyde loam will be encountered in Michigan and adjoining portions of Indiana and Ohio as the soil-survey work progresses in those States.

The surface soil of the Clyde loam, to a depth in excess of 8 inches, is a moderately friable to rather heavy and compact loam, usually

dark gray, brown, or black in color. Near the margins of the smaller areas of this type there is not infrequently a considerable mixture of sandy material, and in such instances the surface soil is more friable and of a lighter gray color. In all of the larger areas where it is developed and in the central portion of even the smaller areas it is almost jet black and contains such large amounts of organic matter as to be almost muck. The depth of the surface soil varies to a considerable degree, ranging from 8 or 10 inches near the margin of the type to a depth of 18 or even 24 inches in the central portion of large areas or in depressed locations occurring in any portion of the type. The subsoil of the Clyde loam is a gray, drab, or blue clay, sometimes mottled with yellow or brown iron stains. In almost all instances this subsoil is stiff, plastic, and impervious, but in certain instances where it is underlain at no great depth either by layers of peat or of marl the subsoil material may be somewhat jointed and less impervious than the average of the type. The Clyde loam in the majority of areas where it has been encountered is stone free, and even gravel is lacking. It is only in marginal areas or in locations where the surface covering of typical Clyde loam is somewhat thin that the stone or gravel of underlying glacial formations becomes evident. In Niagara County, N. Y., a phase of the type which constitutes only a thin covering over underlying glacial material is marked by the presence of stone and bowlders over its surface. This, however, is unusual.

The Clyde loam invariably occupies level or depressed areas which at some previous time have constituted the beds of glacial lakes or of large swamps. Such areas occur not only within the regions formerly occupied by extensions of Lakes Ontario, Erie, and Huron, but also in the beds of many smaller extinct glacial lakes which were ponded between the inequalities of the rolling to ridged glacial drift. In all instances the mineral matter from adjoining uplands was washed down and deposited in the form of fine or coarse sediments within these small or large lake beds, and as the water became shallower vegetation gained a foothold, giving rise to the incorporation of large amounts of mucky or peaty organic remains within the zone that now constitutes the surface soil.

The surface of the Clyde loam is almost invariably level, although in some areas low, rounded knolls and gentle swells within the general area of the ancient lake beds may also be covered by the same characteristic mucky swamp deposits. In all cases the area of the Clyde loam is distinctly depressed below the level of adjoining glaciated uplands and glacial moraines or below the level of the marginal glacial lake deposits.

The altitude of the surface of the Clyde loam varies considerably in the different areas where it has been encountered. Thus in

Niagara County, N. Y., the surface of the type ranges from 300 to 600 feet above sea level, while in the vicinity of Saginaw Bay, in the southern peninsula of Michigan, it lies from approximately 600 feet to about 750 feet above tide. Other separate areas in southern Michigan and northern Indiana have about the same altitude.

In all cases the Clyde loam is either poorly drained at the present time or was poorly drained prior to its occupation for agricultural purposes. In practically all areas where it occurs the Clyde loam constituted wooded swamps or grass-grown marshes in the days of pioneer occupation, and in the majority of instances other upland soils were first cleared and occupied. Later the obstructed natural drainage was improved by the straightening of streams and the opening of drainage ditches, and gradually increasing areas of this black mucky soil have been brought under cultivation. The Clyde loam in its undrained condition, wherever it is encountered, either constitutes swamp not occupied for any agricultural purpose or else forms pasture lands upon which cattle are grazed during the later months of the summer, or where, in the treeless areas, swamp grass is cut for hay. It has only been through the establishment of artificial drainage that this soil has been made available for agricultural use.

Owing to the swampy or semiswampy condition of the Clyde loam prior to drainage, the surface soil is frequently found to be in a puddled, compact state, sticky and impervious when wet and drying out to a clodded or cementlike surface when dry. These effects of poor drainage are emphasized where the finer-grained material is found in lower lying areas which have been under cultivation for only a short time. In such cases the soil proper is frequently stiff and sticky and clods badly when plowed. The continued cultivation of the type, however, and the long-continued operation of frost upon well-drained areas tends to correct this condition and to make the Clyde loam an extremely valuable soil for the production of the majority of the general farm crops suited to the temperate climate within which the type is most extensively developed.

In the case of the Clyde loam a larger acreage of the type is devoted to the production of grass for the cutting of hay than to any other crop. The type is not only well suited to produce large yields, but the management of the soil and of the general farming system in the areas where it occurs has brought about a crop rotation usually consisting of one year devoted to the production of a hoed crop, one or two years devoted to small grain growing, to be succeeded by two, three, or even five years of grass production in the course of the rotation. Because of the adoption of such long-term rotations, in which the land is frequently occupied during half of the entire period by the stand of grass, the acreage of this crop

far exceeds that given either to the small grains or to the hoed crops. The yields of hay vary considerably in the different areas where the Clyde loam has been encountered. In general, in southern Michigan, northern Indiana, and western New York, the yields of hay range from 1¼ to 2 or even 2½ tons per acre. The average yields for the Clyde loam in these locations may be confidently stated at 1½ tons per acre, or greater, dependent somewhat upon seasonal variations in the rainfall. Mixed timothy and clover constitute the principal acreage, although upon the better drained areas clover, seeded alone, is an important crop, both for the production of hay and, in central Michigan, for the production of seed. The alsike clover and the medium red clover are used to a considerable extent both in mixed and pure seeding. It has been found that the alsike clover will make an excellent growth even where drainage has not been thoroughly established, while the medium red clover is somewhat more exacting and requires good to perfect drainage to produce its maximum yields.

Among the small grains wheat is the most important, although the acreage devoted to this crop in the more eastern States is decreasing and the yields are not especially high. They range from 10 or 12 bushels per acre to 20 bushels or more. The average is not much more than 15 bushels per acre. This is, however, in excess of the yields secured upon many of the upland soils in the same general region. Oats are even better suited to the Clyde loam than either winter or spring wheat, and the yields are high in the different areas where the crop is grown. In Michigan the yields range from 35 to 60 bushels per acre, while the general average through a long period of time may be stated at 40 bushels per acre, or somewhat greater. Consequently the oat crop is, to a considerable extent, displacing wheat as the small grain crop. Aside from a tendency toward excessive growth of straw, the Clyde loam constitutes an almost ideal soil for oat production.

In all of the areas where the Clyde loam is developed, corn constitutes its most extensive intertilled crop. The yields are fair to good, ranging from 25 to 45 bushels per acre with a general average of about 35 bushels. Its use for corn growing is shown in Plate III, figure 1.

Many thousands of acres of sugar beets are annually grown upon the Clyde loam in the southern peninsula of Michigan, and there is a strong tendency to increase this acreage in all localities where an adequate supply of labor for the care of the crop can be obtained. The average yield ranges from 7 to 10 tons per acre with exceptional yields as high as 15 to 18 tons.

Beans are grown to some extent as an intertilled crop, preceding either wheat or oats, in both Michigan and Indiana. The yields are

good, ranging from 18 to 25 bushels per acre, with an average yield of 20 bushels. Rye, barley, and buckwheat are also produced to a small extent, giving fair yields.

In some localities there are also small acreages planted to cabbage or celery, the former crop yielding from 8 to 15 tons per acre, with an average of about 12 tons. The quality of the cabbage produced upon the Clyde loam is reported to be excellent. Only a small area of either onions, peppermint, or strawberries, is now produced upon the type, although it is well suited to the growing of each of these crops when economic conditions are favorable.

The farm equipment upon the Clyde loam does not differ materially from the equipment upon other soils in the same general regions. It may be said that larger teams and heavier tools are required for the perfect tillage of this soil than upon any others of similar or lighter texture. The somewhat plastic and dense character of both the surface soil and the subsoil requires deep plowing and thorough subsequent tillage in order to maintain the surface soil in mellow, friable condition. Since the Clyde loam is practically stone free in the majority of areas the use of disk plows and disk harrows is easily possible. The employment of such machinery should obviate the tendency toward the forming of a plow sole or "hardpan" at the normal depth of plowing, a difficulty sometimes encountered in the use of the ordinary turning plow.

The dominance of grass, oats, and corn as the principal crops upon the Clyde loam led to the introduction of dairying as an important adjunct to crop production in the early days of the occupation of this type. The excellent pasturage afforded, the heavy cutting of hay, the large yields of oats, and the satisfactory yield of corn, all led the pioneer farmers, who were usually predisposed to dairying from their experiences in their former locations, to adopt this form of crop disposal. The dairy farms upon the Clyde loam, particularly in Michigan and Indiana, are apparently among the most profitable and best maintained farms in the region. Upon these dairy farms a considerable amount of stable manure is annually returned to the fields and crop yields are maintained at or above the average for the general locality. The production of wheat has largely been superseded by the production of corn and oats upon the majority of dairy farms. The building equipment is somewhat more elaborate than upon the general-crop farms found upon the Clyde loam, because of the necessity for housing the stock and the roughage for feeding purposes.

CLYDE SILT LOAM.

Seven areas of the Clyde silt loam have been encountered in the course of the soil survey work. Four of these are in southern and central Wisconsin, and they comprise by far the largest acreage

which has yet been found. The total area of this type thus far encountered amounts to 122,368 acres.

The surface soil of the Clyde silt loam, to an average depth of 10 or 12 inches, consists of a dark brown or almost black silt loam. It contains a large quantity of organic matter and is rarely gritty or friable. The subsoil is a dark gray or drab silty clay loam which is decidedly compact and sticky. The subsoil occasionally contains some fine gravel and pockets or lenses of sand. In some areas, particularly in the Saginaw area, Michigan, bowlders are scattered over the surface of the higher lying portion of the type. In general it is nearly stone free.

Usually the surface of the Clyde silt loam is nearly level or gently sloping. It is almost always depressed below the level of surrounding upland soil types, although in one or two areas where the Clyde silt loam occupies upland positions its surface is gently rolling. In almost all cases the Clyde silt loam is very poorly drained in its natural condition. This arises from the surface topography of the type and from the fact that it occurs in basins and along stream courses where the natural drainage has not become established. In nearly all cases the drainage of this soil through open ditches and tile underdrainage is necessary before agricultural occupation can take the more intensive forms.

A very small proportion of the total area of the Clyde silt loam has been brought under cultivation. In general the areas are either timbered or occupied by marsh grasses. In the Saginaw area, Michigan, where the type is found upon the gently rolling uplands, practically the entire area has been brought under cultivation for the production of farm crops. Corn, oats, and hay are the chief crops grown upon it in the area, while a limited acreage is devoted to the production of sugar beets. Where the drainage is adequate the crop yields are fair to good. In other localities only small tracts of the Clyde silt loam have been drained and in southern Wisconsin, corn, timothy, alsike clover, oats, peas, and sugar beets constitute the principal crops. Corn gives excellent yields where drainage is good. It has been found in seeding to mixed grasses, that alsike clover is better suited to this soil than red clover, especially until drainage has been thoroughly established.

The Clyde silt loam is naturally a strong productive soil and adequate drainage is the chief need for its more intensive occupation. In many instances a single line of tile would serve to drain considerable areas of this soil while in the larger tracts it would be necessary to install open ditches to serve as main outlets into which lateral tile drains could be led.

CLYDE SILTY CLAY LOAM.

During the progress of soil survey work the Clyde silty clay loam has been mapped in 11 different areas located in New York, Ohio, Indiana, Illinois, and Wisconsin. The total area thus far mapped amounts to 401,984 acres. Additional areas of considerable extent will undoubtedly be encountered in these regions during the progress of soil survey work.

The surface soil of the Clyde silty clay loam to an average depth of 10 inches is a dark-brown to black sticky, silty clay loam. When wet it is a dull black in color and decidedly plastic and claylike. Upon becoming partially dried it assumes a lighter brown or gray or grayish-brown color and usually develops a granulated or crumb-like structure. Nearer the margins of the areas of this type the color is usually a lighter brown, the surface soil may have a depth of only 5 or 6 inches, and the admixture of coarser grained material sometimes renders it rather more loamy than the typical area.

The subsoil to a depth ranging from 15 to 20 inches is most frequently a dark brown or almost black silty clay loam which becomes gradually lighter colored with depth and at about 2 feet grades into a drab or dark-blue sticky clay loam. This is most frequently underlain by a yellow or mottled yellow and gray plastic clay loam.

There is a considerable variation in the depth of the brown or black material overlying the deeper subsoil. In all of the smaller areas of the type, comprising a few acres in a place, the darker surface material has a depth of about 1 foot. In the larger areas, comprising tracts of several square miles in extent, the dark colored, surface material usually has a total depth of 18 inches to 2 feet. In all of these there is a tendency toward a thickening of the dark surface material toward the central portion of the different areas of the Clyde silty clay loam.

Neither stone nor gravel are commonly found in either the soil or subsoil of this type. In some instances small amounts of gravel may be found around the margins of the different areas or underlying the deeper subsoil.

The Clyde silty clay loam is most extensively developed in basin-like depressions associated with the upland glacial soils throughout western Ohio and central Indiana. It occurs in the hollows and depressions in the rolling area occupied chiefly by the Miami silt loam and the Miami clay loam. It is also found in small ponded or swampy areas associated with the moraines and glacial uplands in New York and Wisconsin. Considerable areas are also found through the Great Lake region, where ancient glacial lakes have become wholly or partially drained. In all cases the areas of the Clyde silty clay loam are marked by nearly level or only slightly

sloping topography. In practically all cases these different areas represent either lakes and ponds or extensive swamps which existed before artificial drainage was supplied. In its natural condition the Clyde silty clay loam supported a heavy growth of deciduous water-loving trees, including several varieties of oak and ash, elm, and silver maple. Treeless areas were covered with a rank growth of sedges and swamp grasses. In the early settlement of the country these swampy areas were left undrained, and it is only within more recent times that large areas of the Clyde silty clay loam have been redeemed for agricultural uses through the installation of expensive open drainage ditches and the laying of tile underdrains. In some of the smaller areas the cutting of a single drainage ditch has frequently been adequate to drain the type, while larger areas have been brought under cultivation through the extensive community ditches into which individual farms and fields have been drained by means of tile. At the present time nearly all of the larger areas and many of the smaller tracts have been thus improved, and probably 75 per cent of the total area of the type is now used for the production of some crop.

The Clyde silty clay loam consists of poorly drained areas in the glacial till upland, of swampy tracts along some of the smaller streams, and of areas of previously swampy land in the basins of extinct glacial lakes. The surface material to a depth of 2 feet or more usually consists of a mingling of silty material washed in from the surrounding uplands and of a large amount of partially decayed organic matter contributed by the marsh vegetation which flourished under previous conditions.

The Clyde silty clay loam requires rather careful management to secure the best crop results. If it is plowed and harrowed when either too moist or too dry it is liable to become baked or clodded, with a corresponding decrease in crop production. When it is plowed in the proper condition of moisture the surface soil crumbles into a granular loamy mass capable of producing excellent crops. It is upon thoroughly drained areas that the best results are obtained, and drainage is the most fundamental form of improvement for this type.

In practically all of the areas where the Clyde silty clay loam has been adequately drained corn constitutes the chief crop. It is usually planted for two or more years in succession before being followed by a small grain crop. In some instances it has been grown for 10 or 15 years without serious diminution in yield. Corn produces from 40 to 80 bushels per acre, with a general average in excess of 45 bushels per acre. Both the yellow and white dent varieties are grown. A considerable acreage of corn is grown for cutting into the silo, giving yields of 12 to 15 tons per acre. This use of the corn

FIG. 1.—HARVESTING A HEAVY CORN CROP ON CLYDE LOAM, NEAR SAGINAW, MICH.

FIG. 2.—CABBAGE ON CLYDE CLAY LOAM, NEAR RACINE, WIS.

FIG. 1.—A YIELD OF MORE THAN 60 BUSHELS OF CORN PER ACRE ON CLYDE CLAY IN NORTHERN INDIANA.

FIG. 2.—PASTURING HOGS ON BLUEGRASS AND CLOVER TURF. TILE DRAINED CLYDE CLAY IN NORTHEASTERN INDIANA.

crop prevails in the more northern latitudes where dairying is extensively conducted.

Oats are the important small-grain crop upon the Clyde silty clay loam. This crop usually follows corn in the rotation and under conditions of favorable season gives yields ranging from 40 to 60 bushels per acre. There is a tendency toward the lodging of the grain, especially upon areas where drainage is not complete. The yield is thus somewhat reduced.

Wheat is only grown to a limited extent on the Clyde silty clay loam and with extremely variable yields, which range from 14 to 25 bushels per acre.

The Clyde silty clay loam is an excellent soil for grass production, and large areas are seeded to mixed timothy and clover or to clover alone. The seeding is either made in the spring with the oat crop or the timothy is sown in the fall with the wheat and the clover is harrowed in during the succeeding spring. Yields of hay range from $1\frac{1}{2}$ to $2\frac{1}{2}$ tons per acre, probably averaging about $1\frac{3}{4}$ tons. Some areas of the Clyde silty clay loam where drainage has only been partially established support a heavy growth of marsh grasses, which are either cut for hay or are utilized as pasturage. The yields of marsh hay range from 1 to 2 tons per acre.

Special crops are grown only to a limited extent on the Clyde silty clay loam. In some areas in Wisconsin sugar beets are grown, giving yields of 12 to 18 tons per acre. In that State, also, both cabbage and onions are produced upon this soil, the former giving yields of 12 to 15 tons and the latter 300 to 500 bushels per acre. Irish potatoes are grown to a limited extent, producing yields of 100 to 300 bushels per acre. The potatoes are usually not of first quality.

The most common rotation upon the Clyde silty clay loam consists of corn planted for two or more years in succession and followed by oats. Seeding to mixed grass and clover is made with the oat crop. Hay is cut for one or two years and the lands may be pastured for an additional year. The rotation then returns to corn. The value of the Clyde silty clay loam for corn production is so generally recognized that there is a constant tendency to plant corn as often as is possible. In consequence the greatest acreage in grain is usually devoted to this crop. It is probably only exceeded, if at all, by the acreage given to hay.

Very little has been done in the line of fertilizing the Clyde silty clay loam, the majority of farmers depending upon the inherent fertility of the soil for the maintenance of crop yields. Stable manure is used probably more extensively than any other material, being applied to the second or third crop of corn. In some localities a small amount of commercial fertilizer is applied with the small-grain crop.

The Clyde silty clay loam requires the use of heavy work animals and of improved farm machinery for its proper preparation and tillage. These are extensively employed throughout the region where it occurs.

Except where the Clyde silty clay loam is found in tracts covering several square miles, farm buildings are usually located upon some other soil type, most frequently upon some upland soil whose better drainage renders it more suitable for such purposes.

The crops grown upon the Clyde silty clay loam are to a considerable degree fed upon the farm to dairy cows, beef cattle, and hogs. In the more southern localities a part of the corn and oat crop may be sold from the farm. The type in general constitutes an excellent general purpose farming soil used to a limited degree for the growing of special crops and in some localities developed as the basis for the fattening of stock or the dairy industry.

CLYDE CLAY LOAM.

The Clyde clay loam has only been mapped in five areas, in Michigan, New York, Illinois, and Wisconsin, the principal area lying in Racine County, in the last-named State. The total area thus far encountered amounts to 19,392 acres.

The surface soil of the Clyde clay loam to an average depth of 8 or 10 inches is a dark-brown or black loam. It rests upon a yellow or drab colored clay subsoil which is often streaked with iron stains. Very little coarse material is found in either the surface soil or the subsoil.

The Clyde clay loam is confined to level areas somewhat depressed below the level of the country in which it occurs. It occupies either small scattered basinlike areas in the upland or somewhat larger areas in old glacial lake plains. In consequence of its position and of the stiff impervious character of the subsoil, it is almost always poorly drained in its natural condition. In fact, the agricultural occupation of the type is dependent upon the installation of artificial drainage.

Comparatively few of the Clyde clay loam areas are under cultivation, and where it has not been artificially drained the type is either timbered or is used for the cutting of wild hay and for pasture. It is only in the vicinity of Racine, Wis., that any large area of this soil has been occupied for the production of farm crops. In this region the installation of drainage has permitted the production of corn, which gives yields of 40 to 60 bushels per acre; of oats, with yields ranging from 30 to 50 bushels; and of hay, principally timothy, giving yields of 1 to 2 tons per acre.

In the immediate vicinity of Racine, the type is quite extensively devoted to the cultivation of cabbage and onions. Cabbage produces

from 10 to 15 tons per acre, onions 400 to 700 bushels per acre, while potatoes, which are also grown to a small extent, give yields from 150 to 250 bushels per acre. An excellent field of cabbage, grown on the Clyde clay loam, is shown in Plate III, figure 2.

Elsewhere the Clyde clay loam, where appearing in small areas scattered through other soil types, is either tilled to the general farm crops or, where occurring in larger areas, is utilized mainly for pastures.

CLYDE CLAY.

Next to the Clyde loam the Clyde clay is the most extensively developed soil type of the series. It has been encountered in eight different soil-survey areas, located in New York, Ohio, Indiana, Illinois, and Michigan. A total area of 319,424 acres has been mapped, of which considerably more than one-half is found in the soil survey of the Toledo area, Ohio, where 165,056 acres occur. It is probable that other large areas will be encountered in the Maumee basin and in the area of glacial Lake Saginaw, not yet covered by soil surveys.

The surface soil of the Clyde clay, wherever it has been encountered, is characteristically a dark-gray, drab, or nearly black clay loam. It is well filled with organic matter to a depth of 8 or 10 inches, and this renders the surface soil considerably more friable and easily worked than would ordinarily be the case with material of such fine texture. There is usually a strong tendency toward granulation of the surface soil, due to the high amount of organic matter contained and to the fact that both the soil and subsoil are somewhat calcareous. The subsoil to a depth in excess of 36 inches is a lighter gray, drab, or mottled yellow and gray clay. It is dense and sticky when wet, but becomes intersected with numerous joints and crevices when properly drained and exposed to the action of the atmosphere. It frequently contains gravel, the quantity varying from a few scattered pebbles to a considerable percentage of the soil mass. Neither the soil nor the subsoil contain any considerable number of stones of larger size. In other cases it is free from any trace of gravel and stone and consists of laminated or massive lake clay. In the former instance it is probable that the type constitutes merely a thin surface veneering of glacial lake or swamp material over the underlying till or water-laid glacial deposits. In the latter it is a true glacial-lake deposit.

In all cases the surface soil gives the distinctive evidences, through the color and the accumulation of organic matter, of the swampy condition under which it was formed.

It is a common characteristic of the Clyde clay, possibly more general than with other soils of the series, that the subsoil contains

a high percentage of carbonate of lime. Analyses of numerous samples have shown the lime carbonate content to range from 1 or 2 per cent to as high as 20 or 25 per cent. This arises from the close association of the largest areas of the type with areas where the local limestone was first reworked into the glacial till and later redeposited as a part of the glacial lake sediments which constitute such a large proportion of the total area of the type.

In all areas where it occurs the Clyde clay occupies level or slightly saucer-shaped depressions which are usually below the level not only of other upland soils but even below that of other members of the Clyde series occurring in the same area. In fact, the Clyde clay represents the quiet-water deposition of the ancient glacial lakes, and it was formed in the central portions of the basins of the larger lakes and in depressions in other glacial lake sediments. In such locations the deposition of mineral matter was not usually as great as nearer shore lines or stream deltas, and the deposits were finer grained than in the case of the materials giving the other members of the series.

The surface of the Clyde clay is almost universally flat or but slightly inclined, and there is abundant evidence that the areas of this type constituted shallow lakes or at most swamps until about the time of the pioneer occupation of the general region. The presence of numerous fresh-water shells, the high organic matter content of the surface soil, and many historical accounts of the original aspect of the country all bear out this conception of the immediate origin of the Clyde clay.

Not until artificial drainage was undertaken either by individuals or by county or State authorities was the greater part of the total area of the Clyde clay susceptible of agricultural occupation. It has only been after the opening of large main ditches, along the boundaries of land sections or along natural drainage ways through which farm drainage might find an outlet, that the land has been brought under even the more extensive forms of cultivation, and the production of intertilled crops has frequently become profitable only after the installation of tile drainage. It is certain that many thousands of acres of this soil type would be very greatly benefited by the extension of tile drainage. The value of this form of improvement has been abundantly demonstrated by numerous cases where the value of the land has been quadrupled through the laying of tile. Usually the increased value of the land has more than paid for the expenditure within 5 to 10 years from the installation of the drains, while it has even been the case that the increased crop production for the same period of time has more than paid the total cost of drainage. It is certain that the crop adaptations of the type

are greatly broadened by drainage and that the yields obtained are greatly increased. The certainty of obtaining a crop under all conditions of precipitation is another advantage to be derived from underdrainage.

Wherever the Clyde clay has been drained sufficiently to render it suitable for corn cultivation that crop exceeds all others in acreage and value. In fact it is one of the best corn soils of the Central States. This is well shown in Plate IV, figure 1. Good yields are only obtained from drained lands, and where drainage has not been effected there is very little corn grown. In northwestern Ohio the value of the Clyde clay for corn production is so well appreciated that more than one-third of the total improved acreage of this soil is planted to corn annually. The yields for counties consisting largely of the Clyde clay range from 38 to 41.5 bushels per acre. It may be said that the average yield of the type in this region is probably in excess of 45 bushels per acre, while the crops grown upon the best drained land frequently exceed 60 bushels per acre. The large-growing dent varieties, requiring a long growing season, are commonly planted. The corn is produced chiefly for the grain, although a minor use is made of silage corn for the feeding of beef cattle and, to a more limited extent, in the feeding of dairy cows. Yields of silage range from 12 to 15 tons per acre.

In other localities it is not so easy to select the figures representing the yields of the Clyde clay, since other soil types dominate it in area and obscure its relative importance. Yet it is producing from 25 to 50 bushels of corn per acre in Niagara County, N. Y., depending upon the local drainage conditions, and even higher yields in Allen County, Ind. In the Saginaw area, Michigan, it has not yet become sufficiently well drained to constitute a first-class corn soil under the somewhat cooler climatic conditions existing there. With tile underdrainage it should be well suited to this crop.

In the more southern areas, where the Clyde clay is an important soil, oats are the crop of next importance to corn in point of acreage. Oats usually occupy from one-fifth to one-fourth of the total improved area of the type. The yields are not relatively so heavy as in the case of corn, but they range from 30 to 50 bushels per acre, with a general average of 40 bushels. There is a tendency toward the lodging of the straw when oats are grown upon this moist soil, so well filled with organic matter, and the yields of harvested grain are as high upon portions of the type which are marked by the gray surface soils as upon the generally more productive, darker-colored phase. In fact, oats are said to yield better crops of grain after the land has been cropped for some years to corn. Wherever the Clyde clay is fairly well drained it is uniformly a good oat-growing soil.

Hay and pasture grasses constitute the chief remaining crop grown upon the Clyde clay. Usually the area devoted to grass growing in the Central States is decidedly subordinate to that given to corn and oats. In New York State grass constitutes the chief crop grown upon the Clyde clay. This arises from the fact that little of the type has been sufficiently drained to make it a suitable soil for the production of intertilled crops. The same is partly true of the Saginaw area, Michigan. In all areas timothy, seeded alone, comprises the largest grass acreage. The Clyde clay is almost an ideal soil for timothy production. It is moist, well supplied with organic matter, and mildly calcareous. Unless the yields are decreased through poor drainage the production frequently exceeds 1¾ tons per acre at a single cutting. Total yields of 2½ tons per acre at two cuttings are not infrequently obtained. In many instances the second crop is cut and thrashed for the seed. Mixed timothy and clover also occupy large areas on the type. Both the red and alsike clovers are seeded with the timothy where the hay is grown for feeding rather than for the city market. Clover is grown alone upon this soil, but to a limited extent. The yields of mixed hay range from 1½ tons to 2½ tons per acre. Clover yields as high as 2 tons with an average of 1½ tons per acre.

Wherever the Clyde clay has become well drained the Kentucky bluegrass spreads naturally over the fields not kept in constant cultivation. It forms a thick mat along the roadsides and invades fields which have been seeded to other grasses for any length of time. Wherever it is permitted to remain it forms an excellent pasturage and, if the land were not usually much more valuable for growing the tilled crops or other grasses, it would constitute one of the best sources of pasturage in the Central States. The use of such a field for pasturing hogs is shown in Plate IV, figure 2.

Where tile drainage has been completely installed and the land fully drained to a depth of 3 feet or more, alfalfa succeeds very well upon the Clyde clay. Drainage is a fundamental essential to success with this crop, but otherwise the soil is in excellent condition for alfalfa seeding. It is productive, well supplied with organic matter, and so calcareous that liming is usually unnecessary. Even the inoculation with the proper bacteria is sometimes naturally secured through the rather general growth of sweet clover or Melilotus throughout the area occupied by the better-drained portions of the type. Upon well-drained fields of alfalfa south of Toledo, Ohio, 3½ to 4 tons of hay per acre are obtained in three or four cuttings each year. Such a field is shown in Plate V, figure 1. The stand of alfalfa usually lasts for four or five years. It is then advisable to plow the land for corn, as Kentucky bluegrass will usually invade the fields to such an extent that tillage for a year and

then reseeding to alfalfa is more profitable than continuing the harvesting of the mixed hay.

Winter wheat is a minor crop upon the Clyde clay, although it was formerly extensively grown. The yields are still above the average for the wheat-growing States, but the increased value of the land has rendered the production even of fairly large crops no longer profitable. Yields of wheat range from 15 to 25 bushels per acre on the Clyde clay.

Within recent years sugar beets have come to be grown to quite an extent upon the Clyde clay. The tonnage secured is good, ranging from 10 to 12 tons per acre of beets of rather high sugar content. The beets are grown to best advantage where tile drainage has been established. They may not be grown where drainage has not been perfected, at least by open ditches. A very uneven stand is obtained where drainage is neglected. It is probable that the Clyde clay is second in value only to the Clyde loam as an eastern sugar-beet soil. The acreage upon this type should be extended as rapidly as factory facilities are provided.

Potatoes are grown on this type only to a very limited extent and chiefly for home use. Wherever another more friable soil is available it should be used for Irish potatoes in preference. Yet yields of 100 bushels or more per acre may be obtained upon well-drained land. The tubers are likely to be rather dense and to cook to a dark color.

It is apparent from the crop adaptations of the Clyde clay that it is a soil whose most productive crops are especially well suited to the fattening of beef cattle, the feeding of dairy cows, and the growing and fattening of hogs. This type of farming is being gradually extended over the different areas of the Clyde clay, although the present dominant form is usually that of producing corn, other grains, and hay for sale. The fact that corn, mixed grasses, bluegrass for pasture, and even alfalfa, may be grown to excellent advantage upon this soil marks it as destined to become more and more a stockgrowing and dairying type.

In all cases where the Clyde clay has been drained and used for tillage forms of agriculture the equipment of farm buildings is that of a prosperous general farming community. The dwellings and outbuildings are most commonly frame structures or the house is of brick. The teams used are among the heaviest and best of the Central States. The implements and machinery used are commonly of improved sorts well suited to the management of a stiff and refractory soil. Yet there are portions of the type where drainage is just becoming established where the old log house and barn still persist and where the improvements have not yet attained to the excellent condition of the longer occupied areas. There are still

thousands of acres of this excellent soil that await drainage and occupation.

CROP USES AND ADAPTATIONS.

A general review of the crop adaptations of the different soils of the Clyde series may be presented in tabular form. The materials from which this tabulation is compiled comprise the results obtained in 26 different soil surveys, located in 6 different States, and covering an aggregate area of more than a million and a quarter acres of the different soils. Because of the widespread distribution of the areas and of the very different conditions of drainage and utilization which are prevalent in these different areas, the tabulation is decidedly generalized, and may be taken to comprehend the chief crop adaptations of each soil type, with local differences of climate and of drainage, either natural or artificial, eliminated, or at least subordinated to a rank of minor importance. The instances considered also comprehend considerable variations in market and transportation facilities, so that the general summary possesses the widest possible application.

This table is to be understood to refer only to the agricultural conditions as they exist at present in the region chiefly occupied by the soils of this series. The table makes no prediction as to ultimate crop adaptations when the soils of this series have become more generally and more thoroughly drained, or when a larger number of different crops has been tried out and the unsuited crops discarded for those which give the best economic results.

Tabular summary of the crop adaptations of soils of the Clyde series.

Soil type.	Specific adaptations.		
	Of prime importance.	Of moderate importance.	May be grown.
Sand group:			
Clyde sand		Rye, beans, early Irish potatoes, clover.	Corn, oats, mixed hay.
Clyde gravelly sand		Rye, buckwheat, clover	Corn, oats.
Clyde fine sand		Rye, Irish potatoes, clover.	Corn, mixed hay.
Sandy loam group:			
Clyde sandy loam		Corn, oats, timothy and clover, beans.	Sugar beets, tomatoes, potatoes, alfalfa.
Clyde stony sandy loam.		Corn, oats, timothy and clover, beans.	Sugar beets, wheat, oats, apples.
Clyde fine sandy loam.	Corn, oats, hay, beans.	Wheat, sugar beets	Cabbage, onions, chicory.
Loam group:			
Clyde loam	Corn, oats, hay, sugar beets, beans.	Wheat, rye, barley, buckwheat.	Cabbage, alfalfa, apples, pears, quinces.
Clyde silt loam	Corn, oats, hay, sugar beets.	Pasturage, in poorly drained areas.	
Clay group:			
Clyde silty clay loam.	Corn, hay, sugar beets.	Oats, barley, cabbage	Late potatoes, cauliflower.
Clyde clay loam	Corn, oats, hay, bluegrass pasture.	Cabbage, onions	Late potatoes (small area cleared and drained).
Clyde clay	Corn, hay, sugar beets, bluegrass pasture.	Wheat, oats	Late potatoes, alfalfa on tile-drained land.

FIG. 1.—THIRD CUTTING OF ALFALFA IN ONE SEASON. TILE DRAINED CLYDE CLAY, NEAR GENOA, OHIO.

FIG. 2.—PULLING SUGAR BEETS, NEAR OWOSSO, MICH.

FIG. 1.—TOPPING BEETS. CLYDE LOAM, NEAR ST. JOHNS, MICH.
Note piles of tops available for stock feeding.

FIG. 2.—LOADING BEETS TO HAUL TO SHIPPING STATION, NEAR GENOA, OHIO.

FIG. 1.—WEIGHING IN AND SAMPLING BEETS PRIOR TO SHIPMENT TO THE SUGAR FACTORY, NEAR OWOSSO, MICH.

FIG. 2.—SHIPPING SUGAR BEETS AND CABBAGE, NEAR RACINE, WIS.

FIG. 1.—LOADING CARS BY MEANS OF CHUTES. A LABOR-SAVING DEVICE IN SHIPPING BEETS.

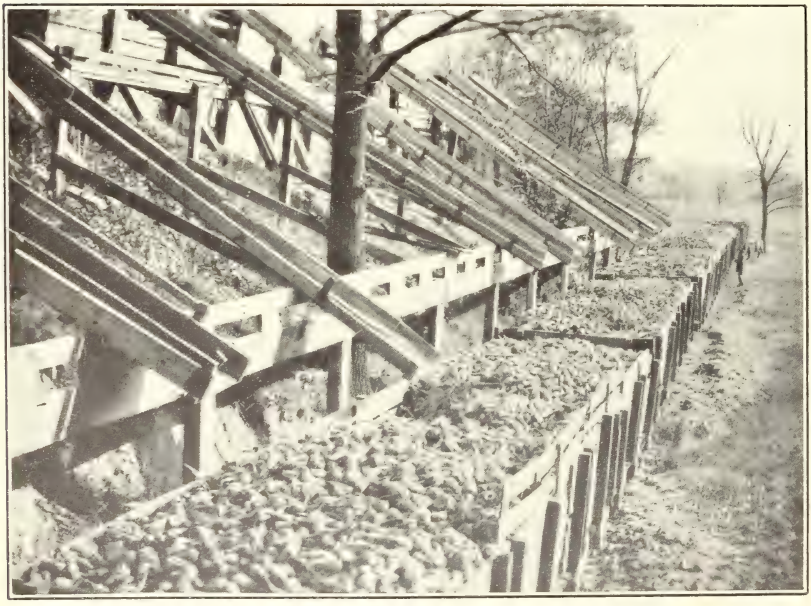

FIG. 2.—A DAY'S LOADING IN THE MICHIGAN SUGAR-BEET TERRITORY.

SUGAR BEETS.

The climatic zone within which sugar beets may be advantageously grown under humid conditions crosses the northern part of the United States, including practically all of the Great Lakes region. Within this section of the country there is a wide diversity in soils and upon many of these different soils the cultivation of the sugar beet has been attempted at one time or another during the last 20 years. As a result of the gradual elimination of soils not well suited to the crop the industry in the north-central States has become somewhat concentrated within areas which are dominated by the soils of the Clyde series. The first intimation of this was obtained by the Bureau of Soils in the summer of 1904, when soil surveys were made in several areas through the southern peninsula of Michigan for the purpose of determining the kinds of soil best suited to the growing of sugar beets upon a commercial scale.

While sugar beets may be grown upon quite a variety of soils[1] it soon became evident from a field study of the soils of the beet-producing region that a typical beet soil must be one which is in such physical condition as to maintain a considerable supply of soil moisture during the growing season without becoming waterlogged; that the best sugar-beet soils were also sufficiently friable to enable the beet roots to penetrate to a considerable depth; that the most successful crops were grown upon soils well supplied with organic matter; and that the tonnage of the crop was generally greatest upon soils which were at least mildly calcareous.

The heavier soils of the Clyde series meet all of these requirements, and it became evident that the sugar content and index of purity of the beets grown upon the different soils of the Clyde series always compared favorably with those of beets grown upon any other soils, while these factors of quality were usually best in beets grown upon the Clyde loam or some very similar soil.

A consideration of the acreage and yield of sugar beets in the lake-region States will serve to show how closely the growing of sugar beets is associated with the soils of the Clyde series.

The State of Michigan reports considerably more than one-fifth of all the acreage of sugar beets grown in the United States in 1909.[2] Only the States of Colorado and California exceed the Michigan acreage, and the latter State only by a few acres. Wisconsin is the only other Eastern State which produces any large acreage, although portions of Ohio and Indiana show small plantings.

[1] See Farmers' Bulletin No. 568, Sugar-beet Growing under Humid Conditions, for a complete discussion of sugar-beet growing.

[2] Census of the United States, 1910.

It is more than a mere coincidence that the counties in Michigan which report over 1,000 acres of sugar beets all contain large areas of the soils of the Clyde series, while all but one of such counties lie in or adjacent to the glacial lake basins where the soils of the series dominate. The six leading Michigan counties in sugar-beet acreage are Bay, Gratiot, Huron, Saginaw, Shiawassee, and Tuscola. Reference to the map, figure 1, will show that all of these counties lie in or adjacent to the area of the old glacial Lake Saginaw. These six counties contain two-thirds of the total acreage of sugar beets grown in the State, and they yield over seven-tenths of the total tonnage produced. A field inspection of the location of the beet acreages in such counties as Shiawassee, where only a portion of the total area lies in the lake basins, only emphasizes the close association of beet production with the glacial lake soils which are classed in the Clyde series. The greatest area devoted to sugar beets is invariably located within the lake basins and upon soils of the Clyde series.

The case in Ohio is even more marked than in Michigan. All of the Ohio counties which report more than 200 acres of beets are so located as to be dominated by the soils of the Clyde series. They lie in or adjacent to the area of the ancient glacial Lake Maumee. The soils are chiefly members of the Clyde series, with the Clyde clay, clay loam, and loam most extensively developed. In this region extensive tile underdrainage has rendered even the more claylike and compact soils suitable for beet growing.

The association of beet-growing areas and the presence of soils of the Clyde series is not so obvious in Wisconsin as in the other two States. This arises from the fact that the soils of the Clyde series are distributed through a large number of small local lake basins, in the main, and the details of beet production are not sufficiently precise to permit of close correlation with these small and scattered areas. Yet a field examination of the territory shows that the soils of the Clyde series in Calumet, Fond du Lac, Kenosha, Milwaukee, Racine, and Waukesha Counties are utilized for beet growing, while smaller areas in Dane and Rock Counties, together with other closely related soils, are the chosen ones for beet growing in these leading beet-producing counties of the State.

Among the soils of the Clyde series the Clyde loam is the best for beet production, although well-drained areas of the Clyde clay and portions of the Clyde fine sandy loam, which are particularly well supplied with organic matter in the surface soil, are also excellent beet soils. The yields upon the Clyde fine sandy loam are not usually so heavy as upon the Clyde loam, while the stiff surface soil of the Clyde clay does not favor the intensive tillage required by the growing crop, and it also offers considerable resistance to root penetration.

Both of these difficulties may be overcome by perfecting the drainage and by the careful preparation of the land prior to seeding to beets.

It is probable that the greatest acreage of sugar beets grown upon any one of the eastern soil types is produced upon the Clyde loam. Yet only a very small percentage of the total available acreage of this one soil has been utilized for sugar-beet growing.

If this and other well-suited types of the Clyde series were also used for sugar-beet growing the acreage devoted to this crop could be considerably increased in the humid region.

Until the soils of the Clyde series have been more completely occupied for beet culture there should be little extension of acreage upon other eastern soils not so well adapted to this crop, although certain upland soils of glacial origin[1] which are well drained and well supplied with organic matter are also available for an even greater development of the beet-sugar industry.

The production of sugar beets in the humid regions of the United States is of such recent origin and the areas within which beets are now grown are so localized that an account of the chief steps in the agricultural practice is essential to show under what conditions beet growing may profitably be undertaken upon added areas of the soils of the Clyde series.

It has been quite generally the custom to plant beets upon land which was in sod during the previous year. The beets thus take about the same place in the rotation as corn and frequently replace a part of the acreage formerly given to that crop. The preparation of the land for beets is about the same as for corn, except that deeper plowing is considered advisable to aid the taproot of the beet in its deeper development. It is essential that thorough cultivation should be given the land prior to planting, so that as many weeds as possible may be germinated and killed before the seeding of the crop. Beets will stand some degree of frost and may be planted at an early period, usually in the latter half of May, even in the more northern localities. The land must be dry at the surface, for standing water will always give an uneven germination and incomplete stand of the plants.

Special beet drills are used and the rows are variously spaced, but usually at 24 to 28 inches. The drills sow the seed thickly, and the crop must be thinned to a stand after the tops have grown to a height of about six inches. This is done entirely by hand labor. Frequently the companies for which the beets are grown contract to furnish all of this hand labor at a stated price per acre. The beets are also hoed once or twice during the season by the best growers, and the sides of the ridges are lightly dressed with the hoe at these times.

[1] The deep phase of the Miami silt loam, particularly in southeastern Wisconsin, is one of the most extensive of these soils.

Frequent cultivation with horse cultivators is essential, and the most successful growers state that the more frequent and the deeper the cultivation the larger the crop. All of the horse labor in connection with the tillage of the crop is performed by the farmer who contracts the acreage.

Under ordinary climatic conditions the crop is ready for harvesting in the middle or latter part of September, throughout the Great Lake region. The first step is that of lifting the beets. This is accomplished by the use of a special tool, built like a large subsoil plow with narrow flanges set to raise the earth as the plow passes between the rows. The beets are thus loosened in the soil. They are pulled by hand and this labor is usually furnished by the company at a fixed charge per acre. (See Pl. V, fig. 2.) The beets are topped in the field as they are pulled (Pl. V, fig. 2, and Pl. VI, fig. 1) and the roots are loaded on wagons (Pl. VI, fig. 2) for transportation directly to the factory or for weighing in (Pl. VII, figs. 1 and 2) and shipment by rail (Pl. VIII, figs. 1 and 2). When weighed, the beets are also sampled to secure representative roots for analysis, as the majority of the factories pay for the beets upon the combined basis of tonnage and sugar content.

The fertilization of lands upon which beets are grown has not been varied greatly from the common farm practice for corn. Stable manure is applied either to the clover sod before plowing or to the beet land after it has been plowed. Even this is omitted in the majority of instances and only the rotting vegetation is depended upon for direct fertilization. Some few growers have used small quantities of complete commercial fertilizer upon beets. From 200 to 300 pounds of a formula commonly used for corn has been used. It analyses about 3 per cent of nitrogen, 9 per cent of phosphoric acid, and 3 per cent of potash. Upon much of the land now used for beet culture it is probable that the use of commercial fertilizers is not fundamentally necessary. Yet the use of lime, in the form of ground limestone, quick lime, slaked in the field and applied broadcast, or the refuse lime from the beet factories would prove decidedly beneficial. Few farm crops are more favorably affected by liming that the sugar beet. It is also desirable that large amounts of organic manures should be thoroughly incorporated with the surface 7 to 9 inches of soil. This is the reason for the general use of clover sod for beet growing. Where possible it would be good practice to apply stable manure to the clover sod before turning it under for the beet crop. This may be done immediately before plowing, or the manure may be broadcasted over the grass land the year previously so that its first effects are gained by the growing grass and the residual benefits are secured by the beets.

The prime necessity for securing large yields of beets upon the Clyde loam and, in fact, upon all of the heavier soils of the Clyde series is adequate drainage. This should be perfected not only for the surface of the land but also for the subsoil to a depth of 2 or 3 feet. It can only be made most effective and more nearly permanent when it is accomplished through thorough tile underdrainage. The outlets for complete farm drainage are usually provided by the county and township ditches and nearly every farm on the Clyde loam or clay loam may be connected with such outlets.

For complete drainage on such dense soils as the Clyde loam, clay loam, and clay, lines of tile should be located at intervals of not more than 60 feet while an interval of 40 feet is not too close in many cases. The tile should be laid at a minimum depth of 2 feet to 30 inches and tile of smaller inside diameter than 4 inches should not commonly be used. The best beet fields upon both the Clyde loam and clay were invariably found to be tiled. The more adequate drainage resulted both in a more nearly perfect stand and in the added length and weight of the mature beets. Danger from poor germination was avoided in the early part of the season, while greater root penetration into the more porous and friable soil gave greater opportunity for maximum growth than upon any of the fields not tile drained. It is estimated by some growers that the cost of tiling the fields is repaid by two or at most three beet crops through increased tonnage and higher sugar content of the beets. Other crops grown in rotation with the beets are, of course, correspondingly benefited.

The yields obtained upon the several soils of the Clyde series have been stated in the general discussion of the different types. For the sake of comparison they may be restated.

While the more sandy members of the series may be used locally for beet growing this is not advisable, and the Clyde fine sandy loam is the coarsest textured soil upon which good yields are consistently obtained. The Clyde fine sandy loam gives average yields of 10 to 12 tons per acre. The Clyde loam produces 7 to 10 tons per acre upon lands not tile drained, and yields of 12 to 18 tons per acre upon tile-drained lands where the greatest care is exercised in the preparation of the land and the fertilization of the beets. It is probable that the general average for the type is in excess of 10 tons per acre, ranging upward on the better drained portions of the type and downward upon lands where drainage is not so complete. A few areas of the Clyde silty clay loam, which have been planted to beets give large yields of relatively low sugar content. The yields are reported to range from 12 to 18 tons. In almost all cases these yields were obtained upon new land, recently drained and placed under cultivation. It is probable that as this soil is used longer for beets and

other crops that the tonnage will somewhat decrease and the sugar content increase. The Clyde clay gives average beet crops ranging between 10 and 12 tons per acre. In northwestern Ohio yields of 15 tons per acre upon well-drained areas of the Clyde clay are not at all unusual. The region where the beets are grown upon the Clyde clay in the Maumee Basin is rather more calcareous than the average, and there has been a general adoption of tile underdrainage.

It is probable that under equal conditions of skill in growing and with all lands properly tile drained, the valuation of the soils of the Clyde series for beet production would about follow the average mechanical composition of the types. The Clyde fine sandy loam would be the coarsest grained soil generally advisable for the crop. The Clyde loam, because of its wide distribution, would remain one of the most important soils for this crop. The Clyde clay would become of far greater importance than at present, but only on the completion of added drainage facilities. The largest yields per acre might be expected from the clay, but the majority of farmers under the natural conditions would probably find that the Clyde loam was the safest soil upon which to plant the crop. It is certain that only limited areas of other upland soils will be found to compete on even terms with these soils of the Clyde series for the extensive and long continued cultivation of beets.

BEANS.

While beans are chiefly grown upon upland soils, both in southern Michigan and western New York, they are also produced upon the better-drained areas of various members of the Clyde series. In Michigan the six leading counties in acreage and production of beans are all counties which contain considerable areas of the more sandy members of this series. These and the upland soils both contribute to the success of bean production.

In New York State, the connection between the soils of the Clyde series and the production of beans is not so close, chiefly because the larger areas of the Clyde soils are not so well drained either naturally or artificially as in more western occurrences.

The soil surveys which have been made in both States show that for bean production the more sandy soils of the series and the better drained areas of the Clyde loam are the soils of the series most successfully used for bean growing. Beans are not reported as a principal crop upon any of the types more dense than the loam, while the larger acreages are always found on the Clyde sandy loam and Clyde fine sandy loam. From the soil survey reports it is possible to give a general idea of the average yields from the different soil types of the Clyde series. The bean yields upon the Clyde sand are obtained from a small acreage only, but average from 12 to 16 bushels per

acre. The yields upon the Clyde sandy loam range from 8 to 20 bushels, with an average around 12 bushels per acre. The small area of the Clyde stony sandy loam, probably because of better drainage, shows a range in yields from 10 to 20 bushels per acre. The Clyde fine sandy loam is one of the types of the series particularly well adapted to bean growing, and the yield is given as ranging from 10 to 25 bushels per acre. It is probable that the general average for the type is about 15 bushels. The portions of the Clyde loam which are particularly well drained are found to give large crops of beans, and the yields range from 18 to 25 bushels per acre, with an average probably exceeding 20 bushels. Such a field is shown in Plate IX, figure 1. There is an excellent opportunity to extend bean production upon this soil as additional areas are improved with tile underdrainage. Beans should constitute a part of the regular crop rotation on the best drained areas of the Clyde loam and should be increasingly grown where the somewhat more profitable sugar-beet crop has not been introduced or may not be grown at present because of distance from shipping point or factory.

Beans require a well-drained soil, naturally well supplied with organic matter, mildly calcareous, and in good fertile condition. They may be grown upon less desirable soils, but the most profitable crops are always secured upon land as fertile as is required for the production of a good crop of corn. For beans the soil must be warm and well drained in order to give good germination and a consequent complete stand. The land should be stone free so that improved machinery may be used to the best advantage for the harvesting of the crop, yet good yields may be obtained upon gravelly and even stony soils.

The best farm practice tends toward planting beans rather late in the season after the surface soil has become well warmed and is in good condition to give high germination, since beans are intolerant of wet, cold weather at planting time. Frequent shallow cultivation is required during the season. Many growers depend upon the residual effects of stable manure applied to a corn crop for the fertilization of the bean crop. Others plant upon stubble land and use small quantities of fertilizer containing a large proportion of phosphoric acid, a smaller proportion of potash, and little nitrogen.

Harvesting usually is accomplished by the use of special machinery which pulls two rows of beans at a time and throws the vines into a windrow from which small bunches are formed by hand. The beans are field cured and usually carried to the barn for more complete curing before thrashing. The harvesting is frequently delayed until after the first light frosts of autumn.

A yield of less than 14 to 15 bushels of beans per acre is not usually profitable because of the amount of labor required for the care and

harvesting of the crop. The best growers, especially upon well-drained land, obtain yields which range from 18 to 25 bushels. These are decidedly profitable, and beans should constitute an important field crop upon all of the better drained and more porous members of the Clyde series of soils.

CABBAGE, ONIONS, AND CHICORY.

Cabbage is grown on a small acreage upon several types of the Clyde series. Upon the Clyde sand and fine sandy loam cabbage is produced for local markets and constitutes an early special crop. The yields range from 8 to 14 tons per acre and the crop is ready for market in August or early September. The total acreage, thus grown, is small and confined to the near vicinity of city markets.

Cabbage is also grown as a shipping or storage crop upon the heavier members of the Clyde series, particularly upon the Clyde loam, clay loam, and silty clay loam. The acreage on the Clyde loam is small, but the yields obtained are fair. A production of 8 to 15 tons per acre of marketable heads is common.

The Clyde clay loam and silty clay loam are far more extensively used for cabbage growing than any other members of the series. In the vicinity of Racine, Wis., several hundred acres of cabbage are annually grown, both for the local city markets and for shipment to southern cities. Danish Ball Head, Flat Dutch, and other shipping varieties are chiefly planted. The crop is grown in regular rotation with other field and truck crops and the average yields vary from 10 to 15 tons per acre, dependent upon seasonal variations, chiefly. It has been found that cabbage should follow onions in the truckers rotation, while they may be grown upon clover sod or after corn in the general farming rotation. Cabbage should not be grown more frequently than once in four years upon the same land in either rotation. This interval is essential to assist in the control of fungous diseases. It is a good practice to lime the land where cabbage is to be grown, using either a ton of burned lime per acre or an equivalent in the form of 2 or more tons of ground limestone. The source of supply for the latter material is near at hand in the case of the Racine, Wis., area and not usually remote in other instances. Stable manure, plowed under in the fall before the crop is planted, constitutes one of the best fertilizers for cabbage, while various commercial fertilizers in moderate amounts are used by some truckers. Usually, the general fertility of the soil is chiefly depended upon for the growing of cabbage upon the Clyde soils. The yields obtained are high under these circumstances. Wherever there is a fair local market or an opportunity to ship to advantage, cabbage growing might well be extended upon the heavier soils of the series.

FIG. 1.—A TYPICAL FIELD OF NAVY BEANS AS GROWN ON THE SOILS OF THE CLYDE SERIES, NEAR FLINT, MICH.

FIG. 2.—UNDRAINED CLYDE FINE SANDY LOAM. BIRCH, TAMARACK, AND RUSHES THE ONLY PRODUCT.

FIG. 1.—A COUNTY DRAINAGE DITCH IN CLYDE LOAM.
Hundreds of square miles of this productive soil have been reclaimed for agricultural uses in this manner.

FIG. 2.—CLEARING THE CLYDE CLAY IN PREPARATION FOR TILE UNDERDRAINAGE.
Note the excellent crop of corn on land already tiled.

Onions are grown to some extent upon various soils of this group. The Clyde fine sandy loam is the type best suited to onion culture, although the Clyde clay loam when well drained and in good physical condition at the surface also constitutes an excellent soil for the crop. On the Clyde fine sandy loam onions yield from 300 to 500 bushels per acre under ordinary conditions of cultivation, while crops in excess of 800 bushels are reported upon the well-drained and heavily fertilized land. The crop is benefited by the application of large quantities of stable manure and by the use of fertilizer high in nitrogen and potash. The use of considerable amounts of organic manure is necessary for the best results with onions upon the Clyde clay loam, as the surface soil must be rendered rather more friable than in the ordinary field condition.

Chicory has been grown as a special crop upon the Clyde sand and Clyde sandy loam in certain parts of Michigan. Both of these soils give yields of approximately 10 tons per acre. The acreage devoted to the crop is rapidly diminishing since other more profitable crops may be grown upon both soil types.

VEGETABLES.

In the vicinity of the larger cities the more sandy members of the Clyde series are used to a rather small extent for market gardening. Wherever drainage has been installed and where stable manures may be obtained from city or other sources the Clyde sand, fine sand, and sandy loam constitute excellent market-garden soils.

Early Irish potatoes, string beans, cucumbers, cabbage for summer marketing, cauliflower, tomatoes, and other garden vegetables are successfully grown upon all of these types. It is probable that celery would prove successful and profitable upon the Clyde sandy loam and fine sandy loam, especially where irrigation of the beds is possible.

DRAINAGE.

Until some form of artificial drainage was instituted, large areas of the different types of the Clyde series in all localities could not be occupied for any form of agriculture more intensive than the grazing of cattle during periods of especially dry weather. The larger part of all of the types now classed as soils of the Clyde series existed only in a swampy condition when the region where they are found was first explored. The northwestern counties of Ohio were long known as the "Black Swamp" country, and it was not until within the last 40 years that any great progress had been made toward the occupation of this land for planting. The adjacent portion of Indiana was similarly a vast swamp until recent times. The region around Saginaw Bay was little used for farming before the early eighties. Even yet

there are thousands of acres of the fertile soils of the Clyde series, located in New York, Ohio, Indiana, Michigan, and Wisconsin, which are either swampy or in such poorly drained condition as to produce only hay or grass for pasturage. Other extensive areas remain in tracts of forest consisting of water-loving trees and undergrowth. (See Pl. IX, fig. 2.)

In so far as the soils of the Clyde series have been reclaimed for agriculture, this has been accomplished through the extensive surface and under drainage of the lands so used. In nearly all of the larger areas occupied by soils of this series, drainage has already been accomplished through community effort in the construction of the larger drainage ditches and through individual effort in the draining of the farm lands into these outlets. This is the present condition in the Maumee Basin, in the Saginaw Bay region, and to a less extent in the smaller areas in Wisconsin where the Clyde soils are found. Such a county drainage ditch is shown in Plate X, figure 1.

There is no single improvement in the condition of the soils of the Clyde series so essential to crop production as drainage. It is not sufficient to provide extensive open ditches for conducting away the surface waters. It is just as essential to provide complete tile underdrainage for the more dense members of the series, in order to reduce the amount of moisture held within the soils and deeper subsoils. The tiling of such land is shown in Plate X, figure 2. Only the shallow rooted crops may be successfully grown upon the Clyde loam and the heavier members of the series until tiling is installed. The largest crop yields observed in any of the soil surveys and during the special examination of the different soils of the series were always located upon tile-drained land or upon land which was so situated as to require little artificial drainage to supplement unusually good natural conditions. The widest ranges in crop adaptations were also closely associated with good natural conditions, or with artificial drainage to supplement unusually good natural conditions.. It would scarcely be possible to overestimate the value of drainage for the soils of this group.

When drained, the soils of the Clyde series are almost universally of great natural fertility and of well-sustained producing power. They are composed of a heterogeneous mixture of many minerals; they are almost universally well supplied with lime—in the subsoil, at least; and they are unusually well provided with partly decayed organic matter in the surface soil. Through these characteristics they are easily worked and friable to a degree unusual in heavy, close-grained, swampy soils. Both the lime and the organic matter assist in maintaining good tillable condition, if the soils are handled with a normal degree of skill.

It is, therefore, very desirable that artificial drainage should be extended in areas where it has already been begun and that steps should be taken to reclaim these fertile and valuable soils in regions where community soil drainage and even local farm drainage are not yet practiced. The value of the reclaimed land is always sufficient to repay the expenditure for any well-planned drainage operations upon the soils of the Clyde series. This has been proved by the success attained in the drainage of hundreds of thousands of acres of the different types.

Many problems of engineering are involved in good tile drainage. For discussion of these the person particularly interested is referred to Farmers' Bulletin No. 524 of the United States Department of Agriculture. Also to the Special Bulletin No. 56 of the Michigan Agricultural Experiment Station and to numerous other experiment station bulletins.

SUMMARY.

The Clyde series includes types with dark-colored surface soils, usually well filled with organic matter, underlain by gray or mottled subsoils.

They have been formed as glacial lake sediments, as terrace deposits along glacial streamways, and as accumulations in small ponds, lakes, or in other positions of obstructed drainage within the glaciated region of the northern United States. The deeper subsoils of the finer grained members of the series are usually calcareous; that is, they contain more than 1 per cent of lime carbonate.

The soils of the Clyde series have been encountered in 37 different areas of which soil surveys have been made, located in 7 different States, and covering an aggregate area of 1,877,700 acres.

They are chiefly found in level or depressed areas within the glacial lake and river terrace province.

Because of the level topography and of prevalent dense subsoil conditions, the different soils of the Clyde series were usually swampy or very poorly drained in their natural condition.

Soils of the Clyde series are found at all elevations from approximately 250 to 800 feet above sea level, throughout the region of the Great Lakes. Usually there is little topographic relief in any small area and the slopes are gentle. Some members of the series consist of low ridges or gently undulating plains.

The soils of the Clyde series are divided into 11 different types upon the basis of differences in texture. These range from gravelly sand to clay.

The crop adaptations of the different soils of the series are given in detail in the text of the bulletin for the different localities in which they occur.

Sugar beets are the most important special crop. A large part of the eastern-grown sugar beets is produced upon the Clyde loam, fine sandy loam, and sandy loam, and even upon the better drained areas of the silty clay loam and the clay. The average yields from the different types show that the tonnage and sugar content of the beets grown upon the Clyde loam and Clyde clay are usually greater than upon any other soils of this or other soil series.

Beans constitute another special crop grown upon the better-drained areas of the soils of the Clyde series, particularly upon the Clyde loam and more sandy types. Good drainage is the chief essential to the production of large yields.

Cabbage, onions, celery, and chicory are locally grown for nearby city markets or for shipment.

Drainage is the most important of all forms of soil improvement upon the soils of the Clyde series. Proper drainage not only increases the yields of crops now grown but also widens the crop adaptations of the different soil types.

Extensive areas of the soils of the Clyde series have been brought under cultivation by means of artificial drainage. Other areas still remain undrained. In the case of these soils the cost of tile drainage is usually repaid within a short time by increased crop yields.

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